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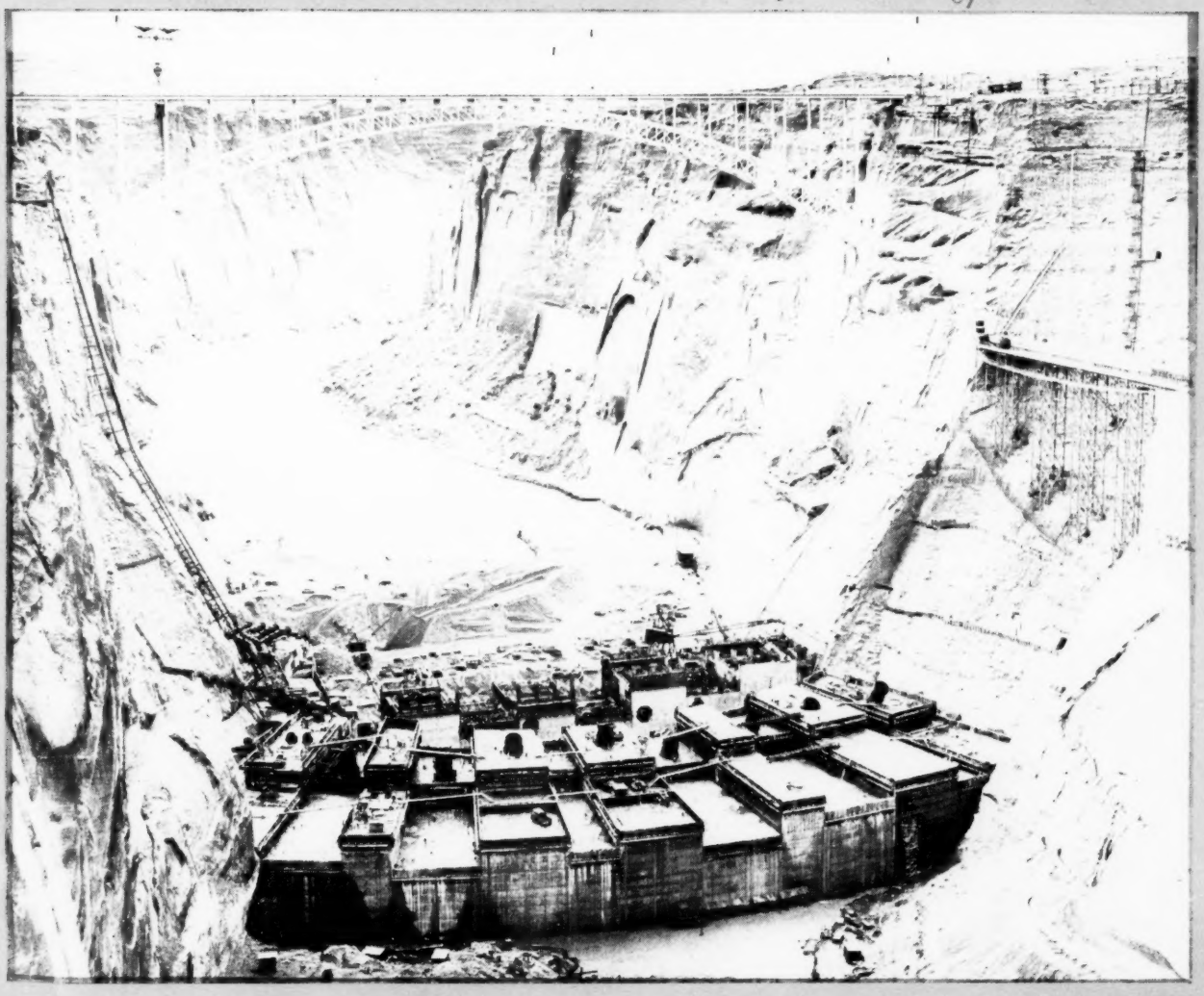

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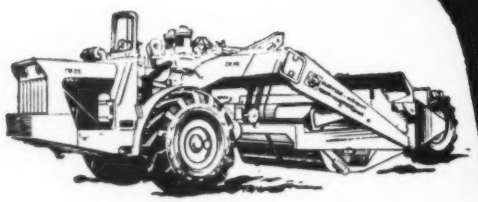

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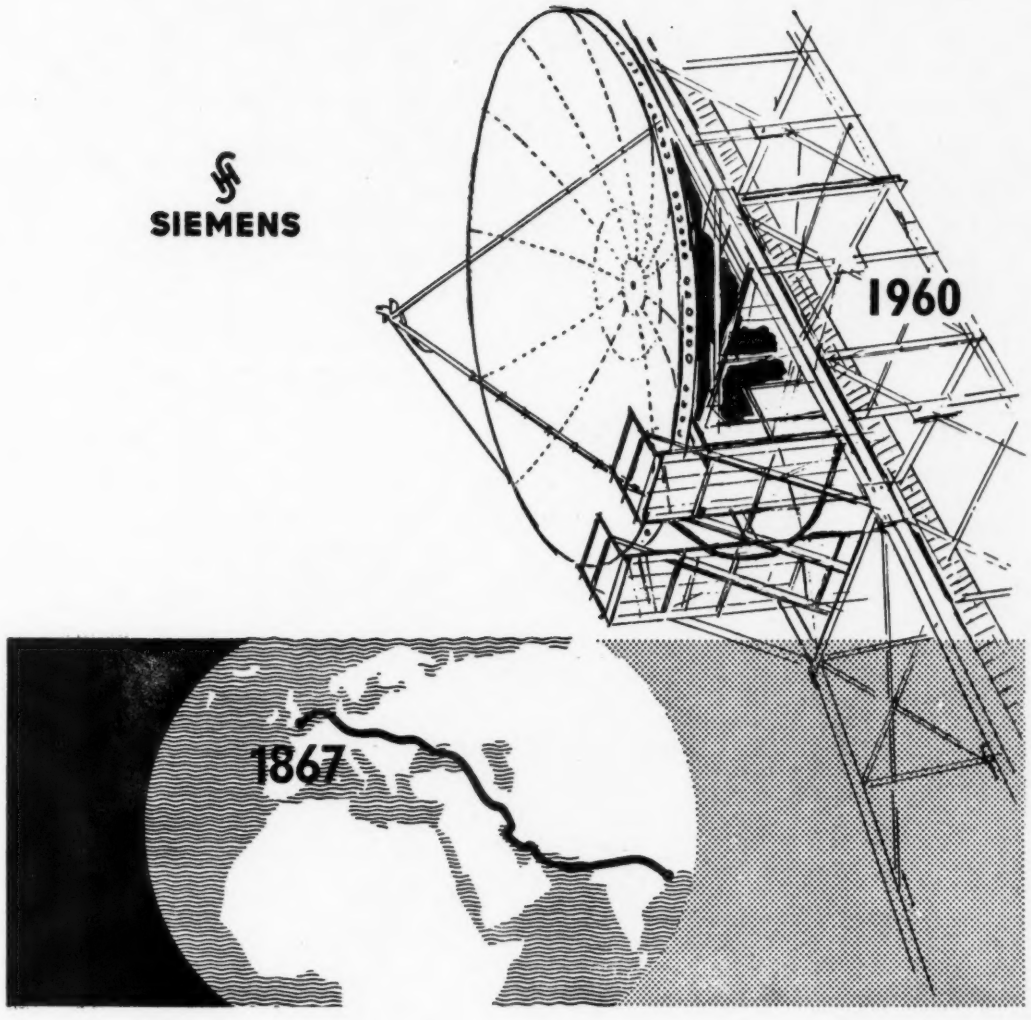

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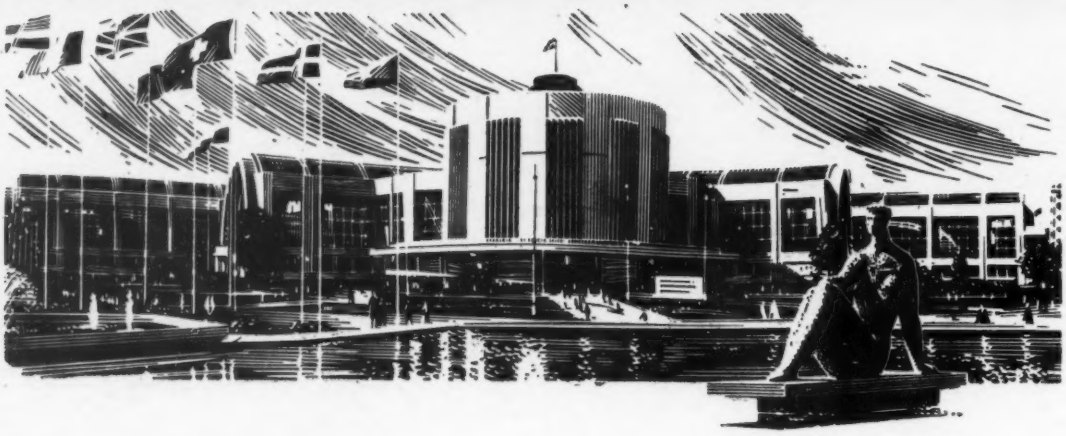

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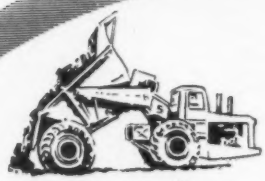

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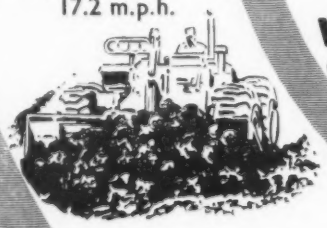

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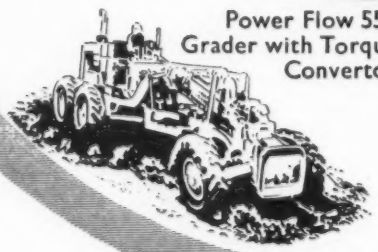

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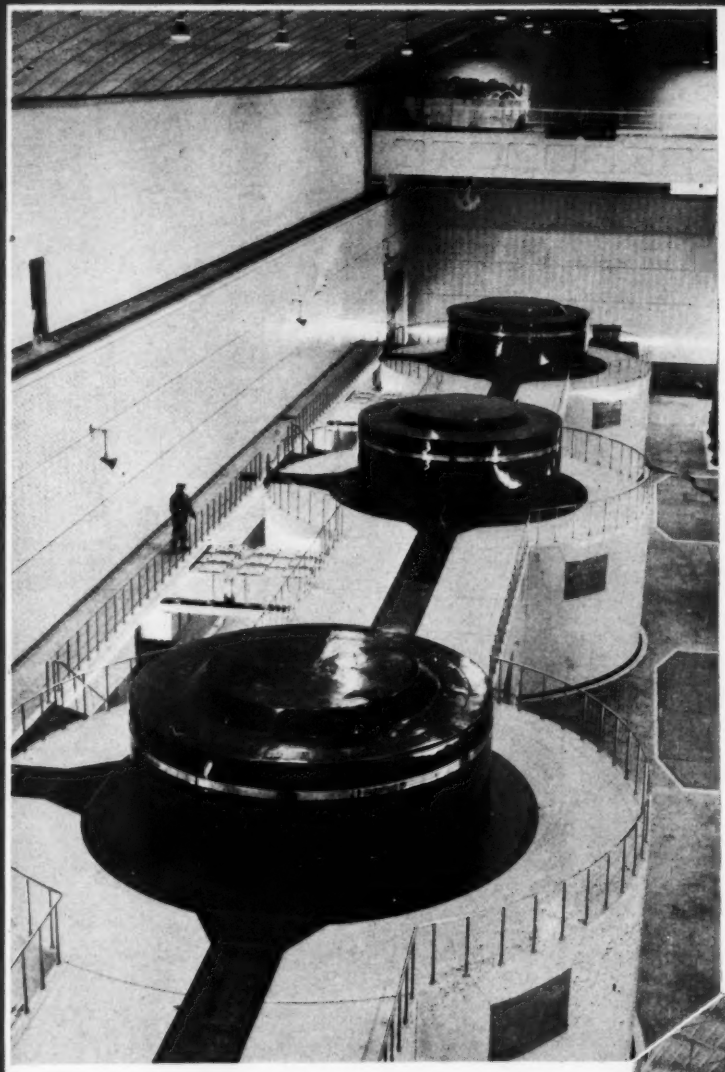

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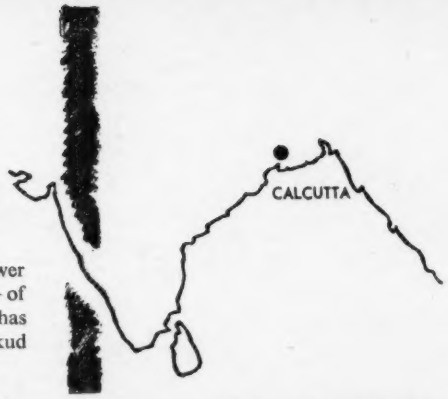
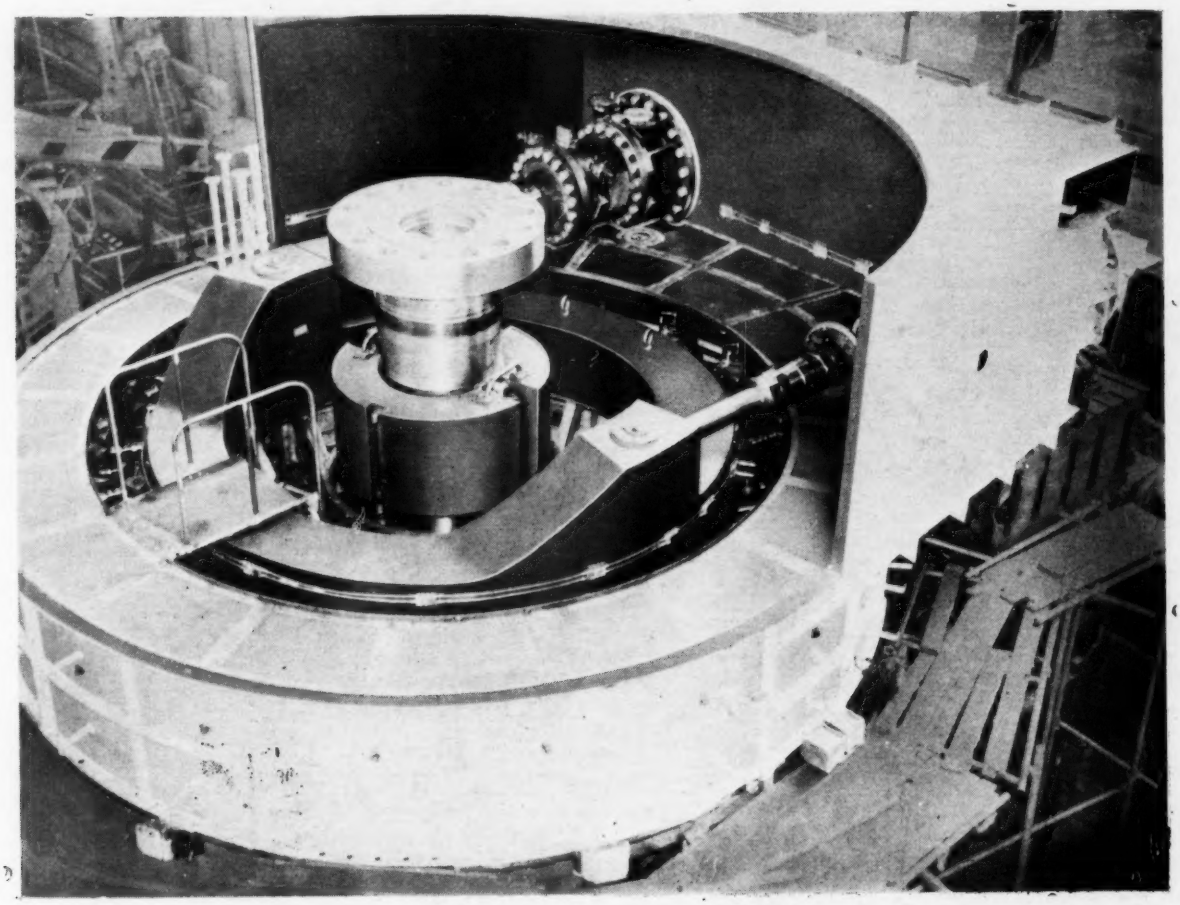


Closely following the official opening of the Bhakra Power Station — equipped with five Francis turbines by Hitachi — of the Punjab State Government, Hitachi, Ltd. of Japan has completed a 52,000 HP Kaplan turbine for India's Hirakud No. 1 Power Station.



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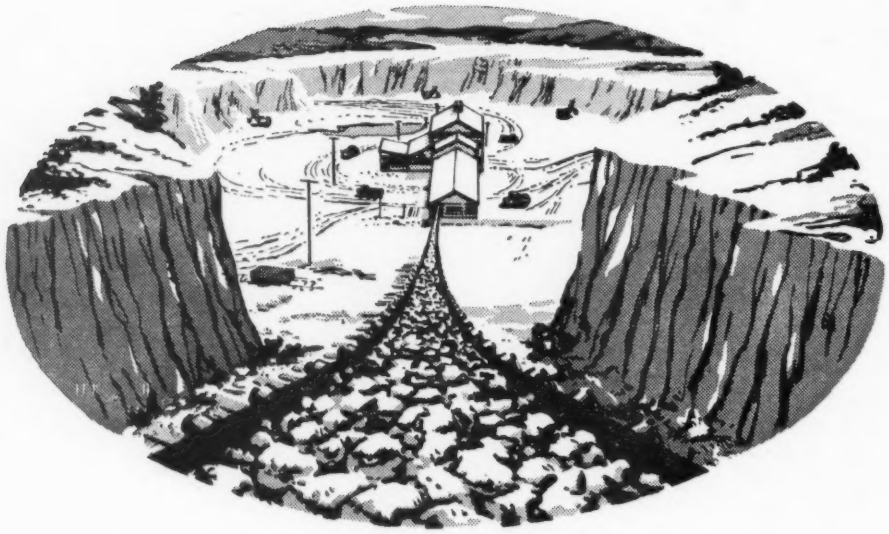

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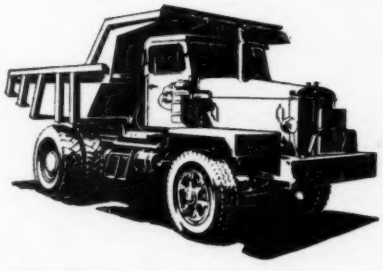

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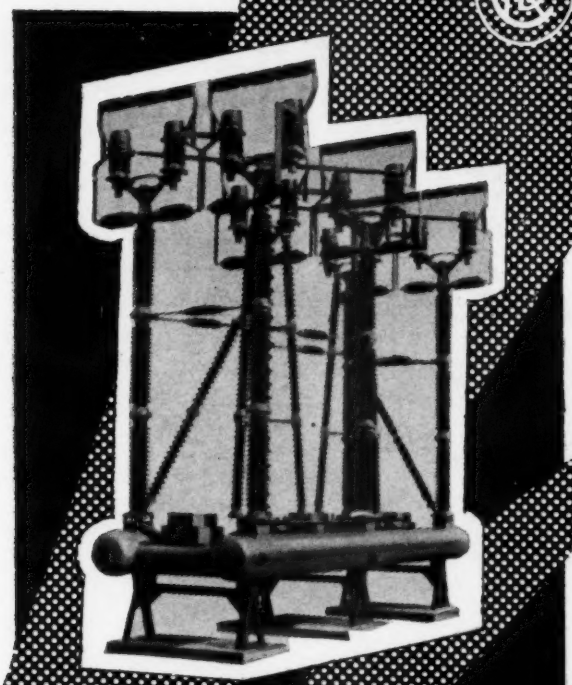

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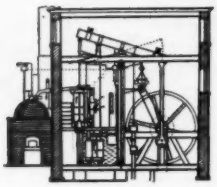

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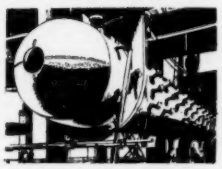

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Editor: K. K. Sinha — Mg. Editor: P. K. Menon

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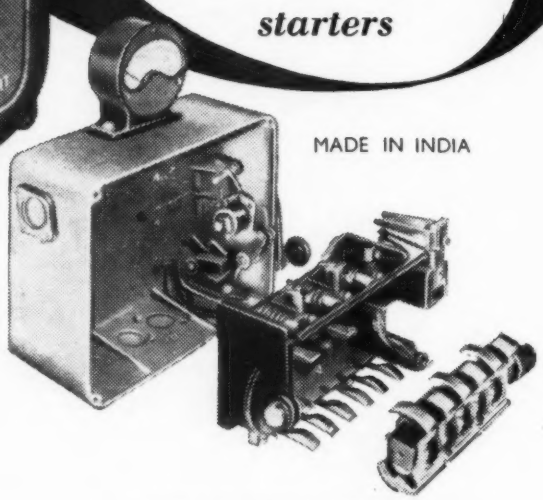

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M. Anwar Arif
Warsak Dam Project Organisation

Warsak Multi-Purpose Project

WARSAK MULTI-PURPOSE POWER AND IRRIGATION Project is a joint undertaking by Pakistan and Canada under the Colombo Plan. This is the first biggest Project of its kind in Pakistan and the biggest ever to be financed by Canada abroad. It was inaugurated by President Field Marshal Mohammad Ayub Khan on January 27, 1961.

Estimated to cost 70 million dollars, this Project has been completed to produce 1,60,000 kW of much needed electricity besides irrigating over 1,20,000 acres of barren land. Later on its output will go up to 2,40,000 kW which will mark completion of the second phase.

Pakistan met most of the rupee expenditure in the shape of wages of over 10,000 Pakistani workers, on the cost of materials procured locally and on the construction and maintenance of civil works like roads, houses, colony, offices and other connected works as well as all transport expenses including ocean freight etc.

The Government of Canada provided the services of their reputed firms of Consulting Engineers and General Contractors, namely M/s H.G. Acres and Company Limited of Niagara Falls and M/s Angus Robertson Limited of Montreal. The former was headed by the Project Manager and the latter by the Manager of Construction. The Government of Canada was also represented at the Project by a senior engineer.

The Chief Engineer appointed by the Government of Pakistan as head of the Warsak Dam Project Organisation (WDPO) was responsible for the administrative and financial control over expenditure in local currency: Policy matters requiring the concurrence of the 3 organisations namely Consultant, Contractors and WDPO were discussed in a Co-ordinating Committee of which the Chief Engineer was the Chairman and most of the problems were solved by this Committee. The other 2 Members of the Committee were the Manager of the firm of Contractors and the Project Manager.

Besides the services of over 150 Canadians at the busiest stages, the Government of Canada also supplied all the heavy construction equipment and machinery for the execution of the Project. In short, that Government met all the foreign exchange expenditure for the Project.

Warsak Project has been described by many who visited it as an excellent example of Commonwealth co-operation under the Colombo Plan because at this Project nationals of Pakistan and Canada worked shoulder to shoulder with a common understanding, co-operation and friendship and for a single aim. In addition to its great economic and productive value, the Project will stand as a symbol of Canadian goodwill towards Pakistan.

History of Project

Warsak Project gets its name from a village known as Warsak village on a nearby hill top. Warsak is a Pushtu word meaning a ridge or spur of a hill where it merges in the plains.

Visitors to the Project can notice that as they approach the Warsak village two miles down-stream the damsite, the Kabul River comes out into the plain from the narrow gorge of hills. It flows downwards for about 40 miles and joins the Indus River near Attock.

Warsak Project has been built on the Kabul River. It is situated about a thousand miles north of Karachi and about eighteen miles north west of the historic city of Peshawar and quite close to the world famous Khyber Pass.

The Kabul River has its source in Afghanistan, where it provides drainage for the eastern part of that country. From Kabul it flows east-ward through the Jalalabad Valley to the Pakistan border. The river has got four main tributaries namely, the Logar, the Panjsher, the Alinagar and the Kunhar or the Chitral River. The last named river is the largest tributary of Kabul River which has its source in Pakistan and contributes almost 50% of its water.

From the Jalalabad Valley to the Peshawar Valley the river runs through a deep gorge between the range of the Khyber hills.

From the border it runs in an easterly direction for about 10 miles, turns southward for further 10 miles and then flow mainly east-ward for 6 miles to Warsak where it debouches into flat land of the Peshawar Valley.

Preliminary Investigations

Investigation work for a suitable damsite started

A pre-construction view of the Kabul River showing the actual site of the proposed Warsak Dam and Power House.

in February, 1949. The investigations included an aerial survey, ground survey, hydrological tests of the river and geological investigation of the river-gorge.

Early investigations were carried out under the supervision of an Anglo-Swedish firm called Merz Rendell Vettan (Pakistan) or M.R.V.P.

On emergence of the Colombo Plan organisation in 1950, the Canadian Government came forward to finance this Project. The Canadian engineers further surveyed the area and as a result of their investigations the present damsite was found satisfactory which offered greater advantages than the rest of the sites previously investigated.

Construction

As a result of the investigations by the Canadian specialists they submitted a plan to the Governments of Canada and Pakistan which was finally adopted by the two Governments. An agreement for the implementation of this Project was signed towards the end of 1954 under which the Canadian Government undertook to meet all the dollar expenditure including the wages of over 150 Canadians workers while Pakistan agreed to meet the rupee cost.

The Canadian engineers started coming to Warsak in 1955 and the actual construction work started early in 1956. Over 10,000 Pakistani workers and 150 Canadians laboured day and night and seven days a week as a result of which this biggest undertaking was completed towards the end of 1960.

Diversion Tunnel

In order to put up a dam at the Kabul River, the first phase of construction was the excavation of a 1700 feet long and 35 feet dia concrete-lined Diversion Tunnel which was completed on north of the river in August, 1957 at a cost of over rupees $1\frac{1}{2}$ crores. In order to divert the Kabul River through this mighty tunnel, two coffer dams of rockfill and earth core were then pushed across the river, one upstream and the other downstream of the damsite. On completion of these temporary dams costing over rupees 32 lakhs, the entire river water started flowing through the Diversion Tunnel in September, 1957. The still water left between the two coffer dams was then pumped out in order to start work in the dried up riverbed for digging foundations of the Main Dam.

Main Dam, construction on which started in September, 1957 was completed early in 1960. The base width of this Dam is 211 feet while at top it is 48 feet. Its foundations went 50 feet to 70 feet deep below the normal bed to reach hard, sound and solid rock.

The Main Dam has been designed to stand pressure of over $5\frac{1}{2}$ lakh cusecs of water whereas records of the past 50 years show that Kabul River has never risen beyond $2\frac{1}{2}$ lakh cusecs. The spillway has nine tainter gates, each $40' \times 40'$, to regulate the flow of water. Running through the Dam is also an inspection gallery $7' \times 13\frac{1}{2}'$ in order to inspect any seepage, cracks or damage to the Dam upstream for any emergency and immediate repairs.

This is the dried up bed of Kabul River while the water has been diverted through the diversion tunnel. Work on the digging of the foundations of the 250 feet high Main Dam is in progress.

Immediately below the Dam a concrete stilling basin has been constructed to provide water cushion to counteract the tremendous force of water which passes over the Dam during periods of flood.

The total cost of the Main Dam and the stilling basin is over rupees eight crores.

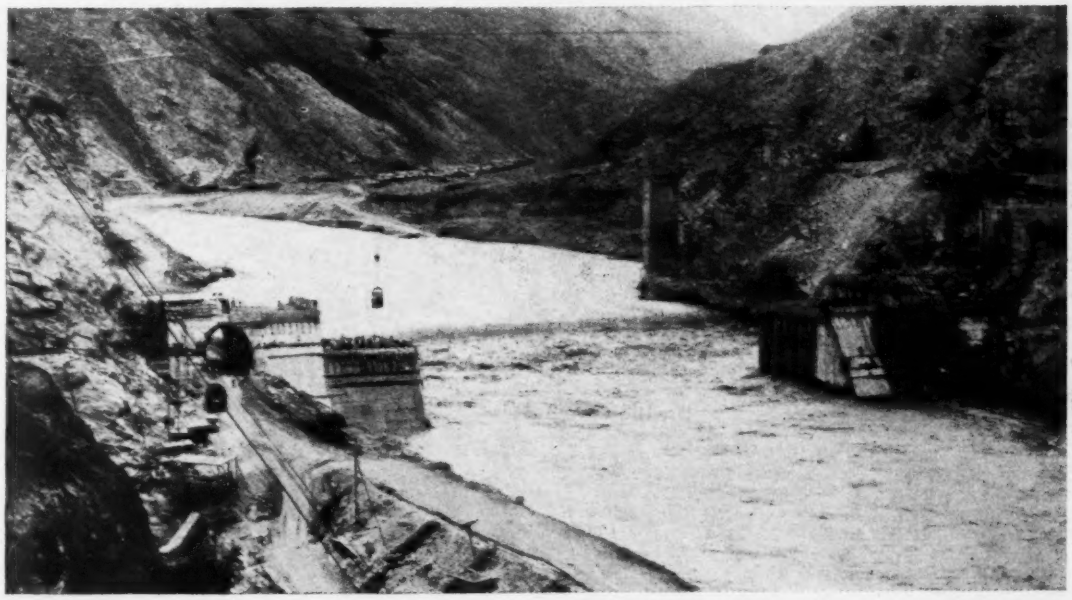
Power Tunnel and Penstocks

In order to feed the Power House, a 717 feet long Power Tunnel with a finished diameter of 39 feet was also completed early in 1960. From a side of the Power Tunnel six penstocks (pipes) of 18 feet diameter each to bring water to the generators were provided. Inside the tunnel is a drop of 145 feet for the water to gain force to run the turbines. The power tunnel and the penstocks cost about rupees two crores.

Power House

The Power House has been built on the right bank of Kabul River. In the first stage, only four generators, each of 40,000 kW. have been installed. They

The Kabul River water having risen beyond the capacity of diversion tunnel is also flowing through the middle portion of the Main Dam while work is in progress at the side blocks.



are now capable of producing 1,60,000 kW. of electricity. With the addition of two more generators in the second stage, the power house will produce 2,40,000 kW of electricity which is almost double the present power load in the main grid in West Pakistan.

Mechanical tests at the first two generators started in April, 1960 when the Kabul River water was allowed to pass through the two penstock tunnels of the Power Tunnel to move the turbines. The tests were found very satisfactory. By the end of April, 1960 these two generating units were commissioned to supply electricity for commercial and domestic use. The remaining two turbines were also commissioned by the end of June, 1960. This marked completion of the first phase of Power House. The total cost on the construction of Power House including the Power House equipment and switching station is about rupees eight crores.

Warsak Lake or Reservoir

With the completion of the Main Dam, the Kabul River was put back to its original bed on 15th January, 1960 by permanently closing the Diversion Tunnel. Within four days the water rose upto the crest or spillway level of the Main Dam, about 150 feet deep, and Kabul River took the shape of a deep lake or reservoir, 26 miles long upto Pakistan-Afghanistan border which is known as Durand Line. The risen water does not in any way effect the Afghan territory as the level at the Durand Line is still the same.

This lake now feeds the Power House turbines to run the generators. When attraction for tourists are developed at this lake, costing rupees eight lakhs the damsite will be a great tourist resort. A scheme is now under consideration of the Pakistan Government for providing facilities for boating, yachting, sailing, fishing, etc. including construction of an air-conditioned hotel with all modern facilities. Fish culture has already been started by stocking various varieties of fish, both ornamental and edible, at two big ponds in the Colony. The Fisheries Department will spend rupees two lakhs each year on the development of fishing at Warsak.

High Power Tension Grid

Warsak Power House will ultimately be linked up with the Sui Gas Thermal Power Station at Multan by a high power grid system. The transmission lines have been practically laid by the West Pakistan Water and Power Development Authority from Warsak to Multan via Wah, Rawalpindi, Kharian and Lyallpur. The laying of the transmission lines has already been completed between Multan and Lyallpur while work continues between Warsak and Lyallpur which is the Central Grid Station. Warsak-Wah section has already been completed.

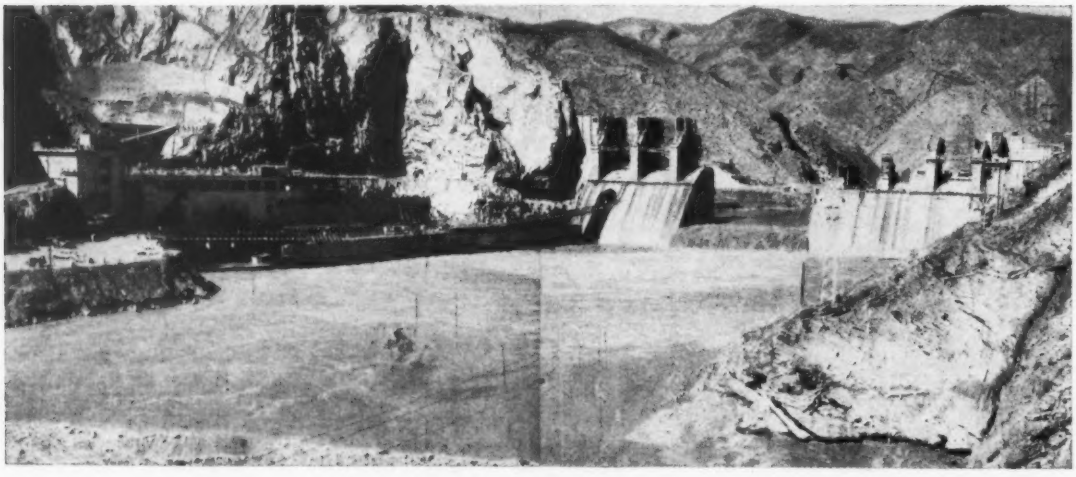
Multan Power Station, capable of producing 1,40,000 kW. of electricity, has also gone into production partially and when linked up with Warsak, the total output from these two biggest power houses of the country will reach 3,00,000 kW.

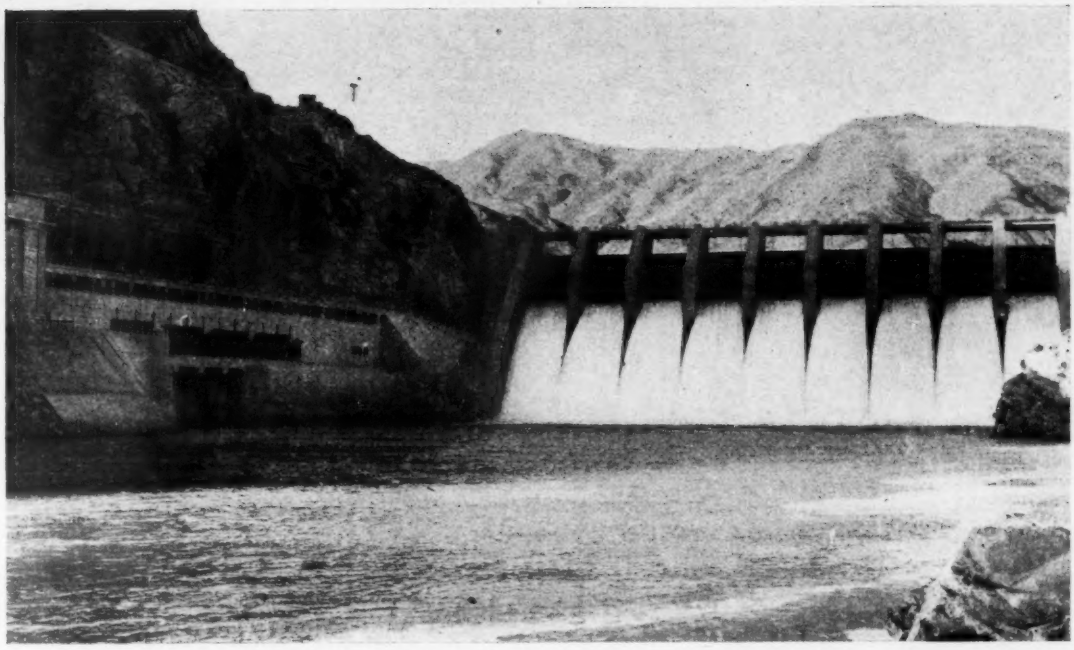
Irrigation

The Project also envisages the construction of high level right and left bank canals to be fed from the reservoir through a $3\frac{1}{2}$ mile long tunnel of 10 feet finished diameter on right bank, and through a 8,600 feet long 6×5 feet tunnel on the left bank.

The $3\frac{1}{2}$ mile long irrigation tunnel has already been excavated. Cutting through the Mullagori hills of Khyber Range, the tunnel opens out at Warsak-Jamrud Road from where two canals, gravity flow and lift, are being dug. The irrigation tunnel was formally declared open on 10th January, 1960 by Lt.-General Mohd Azam Khan, the then Minister of

A view of the Warsak Dam and the Power House at left during the 1959 floods.





Warsak Main Dam after completion.

Works, Housing and Water Resources and now Governor of East Pakistan when he drove from one end to the other on a trolley. This tunnel has now been concrete lined and water from the reservoir will start flowing through this tunnel into one of the two canals in Peshawar Valley within a couple of months. These canals will irrigate, 1,10,000 acres of virgin land which will almost double the present irrigated land around Peshawar. A portion of Khyber Agency will also benefit from the canal. The Left Bank High Level Canal will irrigate about eleven thousand acres of land in the Mohmand tribal area.

Advantages

Food crops, sugarcane and fruit will share the newly-irrigated acreage. While additional cane and fruit acreage will give impetus to the existing sugar and fruit processing industries in the Peshawar Region extra foodgrains will go a long way towards relieving the food shortage that has haunted the area for a long time now. The new area is expected to yield annually about seventy thousand tons of cash crops and foodgrains, augmenting at the same time, *the annual national income by well over seventeen million rupees.*

The most important nation-building aspect of the project, however, is the production of cheap electricity which will impart a tremendous fillip to industrial development in West Pakistan. In addition to running heavy, medium and small-scale industries, Warsak electricity will also considerably help to run the tube wells to fight the menace of salinity and water-logging. This electricity will also be provided to hundreds of villages.

Pakistani Labour Force

With the job now almost complete the number of Pakistani workers has now come down considerably. Majority of them were tribesmen and other Pushtu-speaking people. Their wages were the best available in any Project area in the sub-continent. And what is more important, they have learnt lucrative trades. After the completion of Warsak Project, they are now being switched over to other Projects in West Pakistan. The training they have received on this Project, the first of its kind in Pakistan, is as important as the power production itself. As a result, these workers are now an asset to the Nation.

The Project authorities were keenly looking after their welfare. Since majority of them lived around the damsite area, they were provided free non-family accommodation and free electricity. They were provided subsidized meals from the Government canteens costing just over four annas per head per meal. They and their families were provided expert medical treatment free of cost. The 50-bed hospital situated in the Colony was equipped with the most modern equipment like X-ray, laboratory, operation theatre, etc. Two Canadian and two Pakistani doctors and a number of Canadian and Pakistani nurses gave an excellent treatment and care to the patients

(Continued on page 12)

AROUND THE WORLD...
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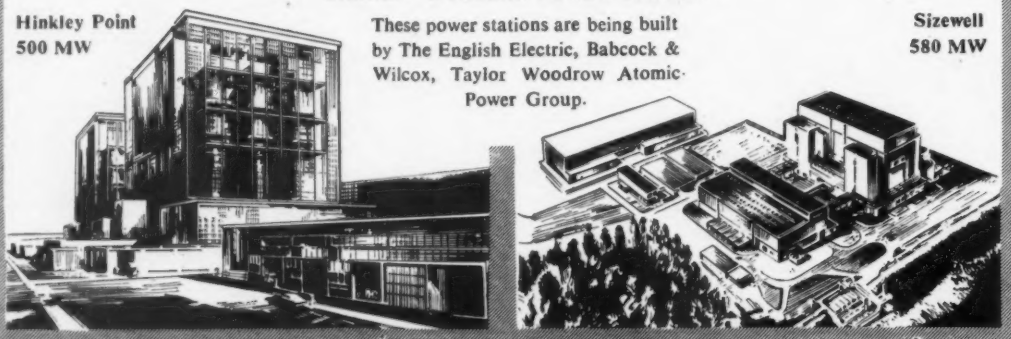
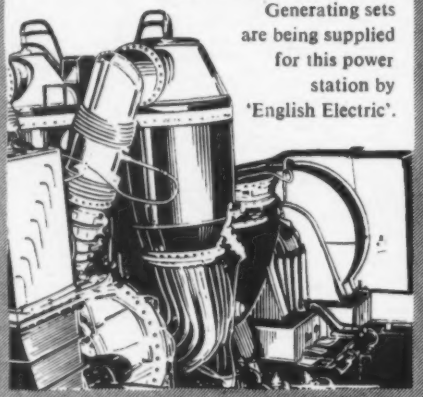
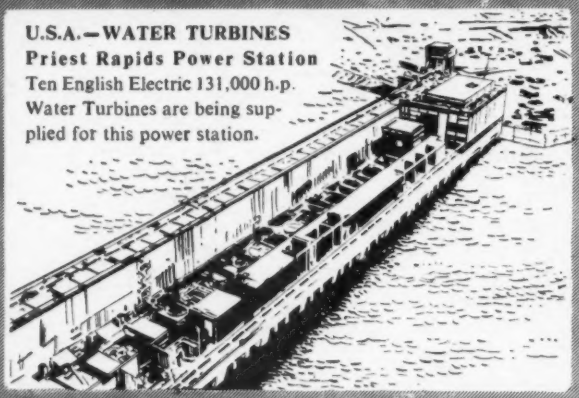


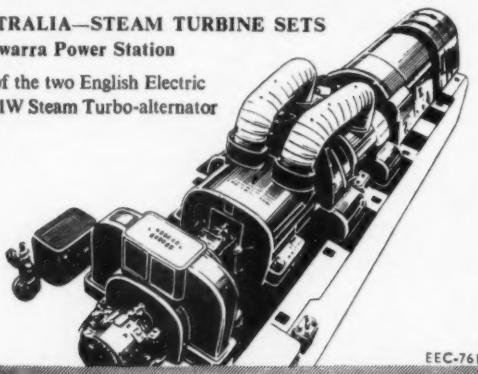
INDIA—GAS TURBINE SETS
Zaloni Power Station
Three 1790 KW Gas Turbine Generating sets are being supplied for this power station by 'English Electric'.



U.S.A.—WATER TURBINES
Priest Rapids Power Station
Ten English Electric 131,000 h.p. Water Turbines are being supplied for this power station.



AUSTRALIA—STEAM TURBINE SETS
Tallawarra Power Station
One of the two English Electric 100 MW Steam Turbo-alternator sets.



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Saeed Minhas
Warsak Dam Project Organisation

Warsak Power House

LOCATED ON THE RIGHT BANK OF THE KABUL RIVER, near the toe of the main dam at Warsak, the 2,40,000 kW power house will go a long way to meet the growing demand of industrial and domestic load in West Pakistan, besides fulfilling the needs of electrically operated tubewells to undo the menace of salinity and water-logging.

Estimated to cost nearly 11 crores, the entire work of the Warsak Power House has been completed in about four years.

In the construction of this power house was employed the skill of Canadian technicians, supplemented by Pakistani personnel and engineers. The entire machinery was supplied by the Government of Canada under the Colombo Plan while the local expenditure in rupees was born by the Government of Pakistan. The power house is designed for a total capacity of 2,40,000 kW to be produced by 6 turbines and generators each capable of generating 40,000 kW at a head of 145 ft. utilising a total discharge of 24,000 cusecs.

Location

The construction of a Power House of the Warsak Dam called for great ingenuity in its location. The narrow gorge of the river and the vertical mountain sides yielded no open space for the Power House. The entire dam length was only sufficient to pass the anticipated flood spill and would not admit of Power House being located at the foot of the dam. Eventually it was decided that the water from the storage reservoir should be taken through a tunnel on the south bank of the river, branching off into the penstocks, below which the turbine units would be inistalled. The side slope of an entire hill had to be blasted and rock removed for locating turbines units and the generators. The total area excavated on the hill side is approximately 500×100 feet involving a total rock excavation of about 5,84,000 cubic yards.

Power House

The Power House area itself consists of the main power building, erection bay area and the control building.

The control building consists of six storeys and houses the cable gallery, elevator, offices and some control equipment. The erection bay area housed the fire pumps and suction lines and strainers in the lower storeys along with the compressors, oil storage tanks etc. In the upper storeys of the erection bay area is building service equipment, battery room and airconditioning equipment.

The main power house building can be divided into two parts, substructure from EL. 1086 to 1149 and super-structure EL. 1149 to 1210. Above EL. 1210 is the switching station.

The superstructure houses the airconditioning cooling units, the top of the generators, transformers, transmitters and the switching station and the 70-ton crane with hoisting machinery to place the generators etc. at proper places.

In the substructure was located the draft tubes taking the water away from the turbines to the tail race. The water to the turbines is led by the penstocks through a spiral casing and that makes the turbines turn and in turn the generators produce electricity.

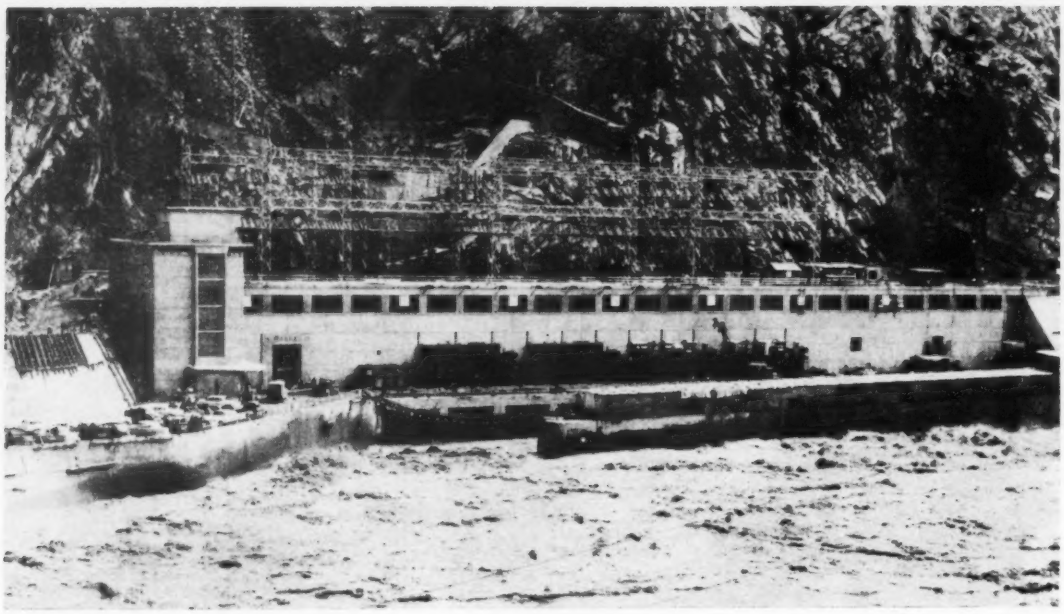
Arrangements were made (i) to control the water entry in the power tunnel at the intake by roller type head gates and for closing off the main power tunnel (ii) to regulate the flow, depending on load condition, into the turbines by operating butterfly valves at the downstream end of the penstocks (iii) to close the draft tubes at downstream end for inspection of the turbines, etc. by sliding gates.

In the first phase, the power plant consists of four installed hydro-electric units, and the necessary auxiliary equipment. Each unit is composed of a generator with a continuous rating of about 40,000 kW at 100% power factor, rated speed being 136 r.p.m. The generator is coupled to the turbine by a vertical shaft.

Provision is made for six turbines but at the moment only four turbine units have been installed. Though the substructure of the remaining two generating units has also been completed, but their installation will be deferred to a later date.

Power Tunnel

The power tunnel connecting the forebay with penstocks serves as a header and is 650′ long, with



A recent view of the Warsak Power House.

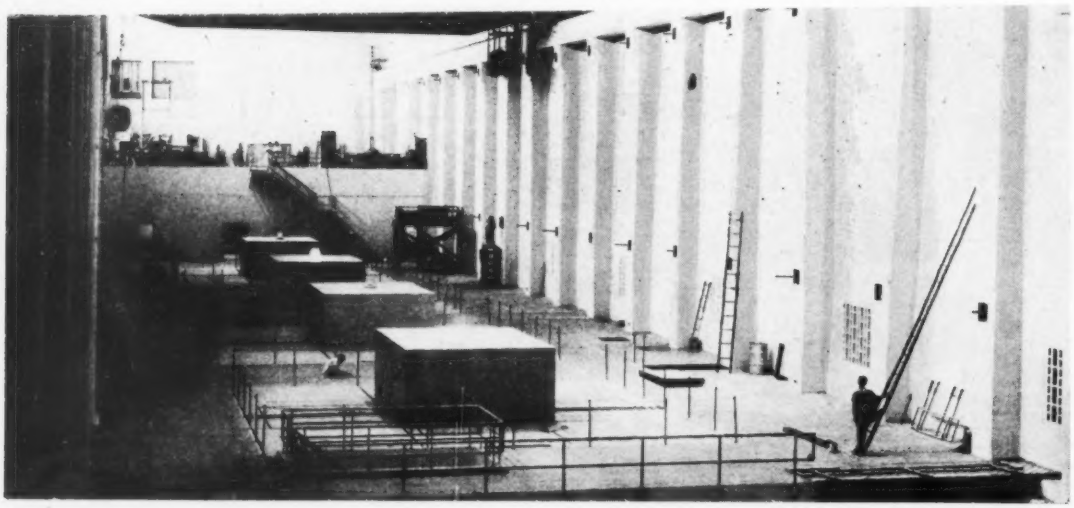
a finished diameter of 39′, while the length of the intake of the power tunnel is 138′. The penstocks are 150′ long with steel liners 120′ long, 18′ diameter to give as smooth a flow as possible. They are properly designed to withstand the effect of water hammer and high head. The capacity of each turbine is 55,000 H.P. at a net head of 145′, but in the first year of their service, the turbines will work at a net head of 135′. The increase in operating head is anticipated due to subsequent retrogression of river bed below the power house.

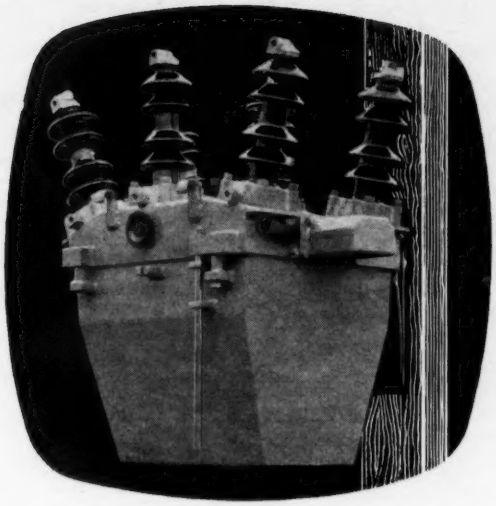
Turbine Operation

The operation of the turbines is restricted by the storage capacity of the Warsak dam reservoir so that the permissible draw-down of the reservoir under which turbines operate, is restricted to 10′ i.e. from elevation 1269 to EL. 1259. The live storage for a draw-down of 10′ during the low supply period is 20,000 acre ft. in a day to warrant running of the six turbines for about 8 hours or 4 turbines for 12 hours in a day. In the minimum flow period, the

(*Continued on page 21*)

An interior view of the Warsak Power House.





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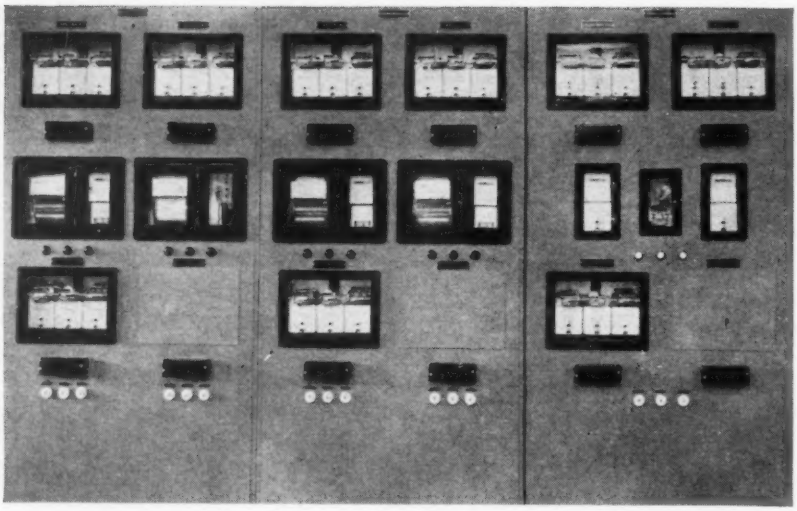

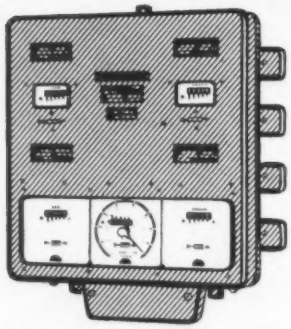

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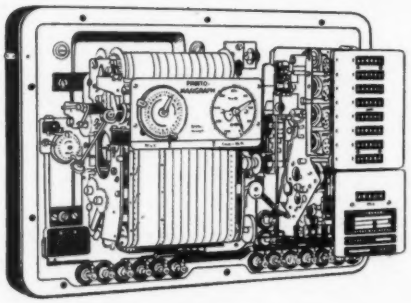

An inside view of Landis & Gyr Printo-Maxigraph and summation meter. It provides simultaneous printing of the average load value in numerals and graphical recording of a corresponding ordinate on the chart strip; clear, easily evaluated records; easy low-cost maintenance; clean recording without liquid ink

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Dr. B. K. R. Prasad
Formerly Chief Engineer, Electricity,
Government of Bombay

Water Power Development in Switzerland

IN SWITZERLAND, WATERFALLS FORM ONE OF THE most important natural resources. The most important rivers of Western & Central Europe have their source in this country, whose position and configuration make it unique from the point of view of hydrology. The rainfall varies from 500 mm to 3000 mm per year (average 1300 mm). The average altitude is 1300 metres and various rivers leave Switzerland at different altitudes—Rhine 245 M, Rhone 336 M, Tessin 137 M, Doubs 422 M, Inn 995 M. These rivers and the various natural lakes through which they flow are the chief factors in the development of hydro power. Some regulating measures have increased the capacity of these lakes in the catchment area. The total catchment area is 1825.55×10^6 cu.m.

The earlier developments were in the vicinity of the lakes, but the later ones used artificial reservoirs and higher heads. The various systems are interconnected by EHT transmission lines. The general characteristics of the hydro resources have influenced the manner of the development. The water courses are of an alpine nature and hence there is a more abundant quantity of water in the summer when snow melts.

Since the first hydro stations were of the run-of the-river type and situated near the towns on the lower courses of the rivers, the energy available was primarily irregulated and was influenced by meteorological conditions and seasonal chances. Power requirements in the country are generally steady, but somewhat higher in the summer than in winter. These variations of an opposing nature had some effect on the Swiss power economy. More plants were installed with higher efficiency. But the fluctuating nature of power production made it necessary to sell surplus power to consumers who could adjust their demands to the fluctuating nature of power generation and for whom a concessional tariff was framed to compensate for their using other sources of power or even stopping operations during short periods of low water.

This inconstant production available during certain seasons and exceeding the normal energy requirements of the consumers, contributed, due to its moderate price, to the development of industries requiring very large amounts of electrical energy, i.e. electro-chemical and electro-metallurgical industries. It is also applicable to electric boilers which can be supplemented by fuel burning boilers. It was also possible to use some surplus power outside Switzerland where they supplemented in an advantageous manner the electro-thermal power production of neighbouring countries.

Thus, during the course of several decades, the exchange of energy between Switzerland and the neighbouring countries became increasingly important. After 1930, the quantity exported from Switzerland was about $1\frac{1}{2}$ billion kWhr, this being $\frac{1}{4}$ of the total production. To achieve this technically, it was necessary to build large generating installations and a large number of transmission lines to connect Swiss networks with foreign undertakings. Good and firm relations were established between the interested companies, useful on both sides not only for normal exchange but also to meet special requirements for mutual aid which has never failed. According to International Laws, the native consumers will have priority and the export of energy is only permitted when the energy can be sold under equivalent conditions abroad. Such an interchange of energy has had a considerable advantage that during the scarcity of energy supply towards the end of World War II, the export of energy was restricted in order to supply the home market with the extra energy required, but also to import energy, when the demand exceeded the available energy from new hydro plants, especially in winter months without imposing many restrictions. This import of energy was effected without compulsion and to the mutual advantage of the parties concerned.

In this connection Switzerland gave financial aid to foreign power companies which lacked adequate capital resources and whose energy resources were inadequate so that they could have hydro and thermal power stations more quickly. They on their part delivered part of the new power as compensation. Several Swiss undertakings collaborated to accelerate considerably the construction work on the Resia pump storage power station in Italy and received as payment 1 billion kWhr spread over a period of 10 years. Some contracts were made with Electricite

de France for the supply of materials for the thermal power stations, payment being made in the form of winter energy. In other cases, a favourable exchange was arranged of a summer energy available in Switzerland or winter energy supplied from foreign thermal stations with a compensation factor of 1 kWhr for 2-3 kWhr summer energy depending upon the quality of energy supplied. Some Swiss companies made long-term contracts with foreign companies for a regular supply of energy from thermal power stations to cover the very large deficiency in energy occurring during a dry year. Sometimes the energy came from distant regions like Belgium with compensation of summer energy.

Even if the energy exchange is big in absolute values it is small compared with the total production of the countries in question. They are of peripheral nature because of the cost of transmission over long distances. The European networks have very high voltages and power transmission capacity and are built for power distribution purposes. Even though not constructed for energy exchanges, they can still be used for that purpose only to some extent.

The Union pour la coordination de la production et du transport de l'electricite founded in 1951 by the electric supply companies of 8 countries for properly coordinating the exploitation of power stations and electrical networks in Europe has been very helpful. It facilitates better utilisation of power production and transmission, helps the neighbours in case of breakdowns or during adverse weather conditions, which is a very valuable function.

The power capacities of different river basins are noted in Table I. About half the water power resources worthy of utilisation has been developed by means of reservoirs. Some are under construction, such as Grand Dixence, Mauvoisin, Maggin Sevrella. Several low head plants like Hupperswill, Wildegg-Brugg and Birsfolden have been built. Some 16 dams have been constructed. In about 15 years all the economically feasible water resources in Switzerland will have been harnessed and hydro power will have reached the mark of 35 billion kWhrs (Max.). Any deficit thereafter will have to be made up by other sources as the demand increases.

Electricity forms 27% of the total energy production the remainder being of coal and other fuels. The present total installed capacity is about 15 billion kWhrs, 46% of which is produced between October and March and the balance 54% the rest of the 6 months. Of the various power schemes; 44% are government owned, 40% private owned and 16% combined enterprises (75% of the energy is derived from the public service utilities). The energy consumption is distributed as follows: agriculture and trades 36%, chemical & metallurgical industries 36%, pumps and boilers 19% and railways 9%. Out of this, about 2 billion kWhrs were exported to neighbouring countries.

The new developments now undertaken will add 7.5 billion kWhrs by 1962 and ultimately to 35 billion kWhrs. The capacity of the artificial reservoirs is 1210×10^6 cu.m. equivalent to 2.2 billion kWhrs. Another 11 new reservoirs will add 620×10^6 cu.m equivalent to 2.0 billion kWhrs. The amount invested in the power schemes is about 5500 million Swiss Francs and the yearly expenditure is estimated at 600 million Swiss Francs.

The mechanisation will proceed and will require more and more energy. This amount which may exceed the capacity of hydro power stations will have to be made up by other sources such as atomic power, which, by that time is expected to produce energy at economical rates though higher than hydro power, which is not replaceable as the resources are perpetual. If other countries safeguard their own interests by constructing atomic power stations, the exchange of energy between countries will diminish as regards relative values, because the unregulated surplus (from run-of-the-river plants) will decrease in importance as regards total production.

Atomic power stations should preferably operate as base load stations steady load during long periods, to be really economical. Storage plants providing controlled energy will have to take up the peak loads and make up the deficit. Such stations will have to be designed and planned to give their entire production during a few hours and have high installed capacity. They can then also be used to a certain extent to maintain some energy exchange with other countries —for peak loads and for night or week-end energy available from thermal power stations having a large number of units which can be made to run at good average loads. These exchanges will be based on evaluation factors connected with the quality of power.

Perhaps in course of time, the regime of the atomic power stations may be such that it may be possible to supply the calories (heat) required by certain large consumers directly without passing through the thermal electric cycle (of poor efficiency) thus combining power agents with other types.

Such a scheme may be imagined for an optimum division between direct consumption of heat and in the form of electricity. The former may be cheaper, but involve high transport charges and could be used by industries very close to the atomic power stations. The latter, though expensive and involves high transmission costs could be distributed all over the existing networks.

Such a combination could perhaps be worked out by providing back pressure turbines in the nuclear power stations, thus improving the thermal efficiency of the power production and also supply low-priced calorific energy to industrial consumers.

Energy is the backbone of industry, a source of security, cleanliness, comfort for crafts and domestic organisations. Therefore a large percentage should be available as electrical energy. In spite of all this, there will be sufficient energy available for exchange for mutual benefits. All the available energy should be used in the most appropriate manner—for the benefit of the people.

An abstract of the power development in different catchment areas is shown in Table II.

TABLE I

TABLE I—Power Capacity of Different River Valleys

	Existing Capacity MW	Projected Capacity MW	Total Power MW
Grisone Rhine	442.5	—	442.5
High Rhine	634.9	178.5	813.4
Oberhasli	388.0	—	388.0
Aare	218.8	—	218.8
Liemat	34.1	—	34.1
Rhone	739.9	1359.0	2096.9
Tessin	386.9	713.5	1100.4
S.B.B. (Railways)	361.4	—	361.4
Total	3206.5	2251.0	5457.5

All power stations are interconnected by 150 kV and 220 kV transmission lines. Certain sections of power areas in South and S.W. are being connected to the north-east section and are being converted to 300 kV system. This will further facilitate interchange of power with Italy, Austria, Germany and France. The power development in the above areas has been organised by various municipalities, power companies and manufacturing firms. The major power schemes are on the Rhone and Rhine catchment area (South and S.W., North and North East of Switzerland). Most of the new power schemes will be completed in 10 or 15 years.

Area	*Stations & Data*
Rhine	9 companies, 18 power stations: 442 MW 1530×10^6 kWh/yr
	Zurich (4 stations) 112 MW & 549×10^6 kWh/yr
	Zevrslia 4 stns 231. 5 MW 533×10^6 kWh/yr
High Rhine	13 power stations—635 MW—4276×10^6 kWh/yr
	Ryburg 108 MW—732×10^6 kWh/yr
	Joint Swiss and French (medium plants at Birsfelden, Basel, N.O.K. Baden, Rheinau, Eglisau) 130 MW, 864×10^6 kWh/yr
	New plants at Koblans Rheinfolden and Savkingen Total 178.5 MW—1063×10^6 kWh/yr
	Total on Rhine proper will be 813 MW—5329×10^6 kWh/yr
Tioino	5 companies with 13 power stations 390 MW—1574×10^6 kWh/yr
	Kraftwerke Maggia 3 power stations 202 MW—792×10^6 kWh/yr
	Aare Tessin AG, 4 power stations 133 MW 610 kWh/yr
	Future planned 9 stations 730 MW 1561 $\times 10^6$ kWh/yr
	Blenie Kraftwerke 4 stations 404 MW 986 $\times 10^6$ kWh/yr
	Maggia 4 stations 182 MW 258×10^6 kWh/yr
	Total 22 stations 1100 MW 3135×10^1 kWh/yr
Rhone	Largest with 30 power stations 2049 MW 6159×10^6 kWh/yr
	28 stations owned by chemical and metallurgical industries 740 MW 2911×10^6 kWh/yr
	Aluminium industry 7 stations 207 MW 994×10^6 kWh/yr
	E.O.S. Lausanne 4 stations 158 MW 511 $\times 10^6$ kWh/yr
	Swiss Federal Railway 4 stations 120 MW 348×10^6 kWh/yr
	New 11 stations 1359 MW 3250×10^6 kWh/yr
	Grand Dixence 2 stations 680 MW 1426 $\times 10^6$ kWh/yr
	Mauvoisin 2 stations 352 MW 761 $\times 10^6$ kWh/yr.

TABLE II

Catchment Area	*Sq. km.*	*Power Potential billion kWhrs*	*New Developments*	*Small Projects*	*Remarks*
Rhine Catchment	36500 (28000 in Switzerland) Includes regions at Constance and Basel (68% of the total Switzerland)	9 (50% in upper Rhine) 25% of Switzerland	1230 MW; 3.3. billion kWhr	132 MW 0.8 billion kWhr	Oberbasil has 7 reservoirs Oberar-Grisone 130MW 69×10^6 kWh Handeck I—88 MW 226×10^6 kWh Handeck II—60 MW 120×10^6 kWh Innertkirchen—210 MW (Underground) 760×10^6 kWh
Rhone Valley		750 MW 2.9 billion kWh	Grand Dixence and Hauvoisin 800 MW & 2000 $\times10^6$ kWh		38 power stations—large glacier discharge area above Lake Geneva offers excellent power potential
Aare Basin		219 MW 1486×10^6 kWh	Goschenen scheme above Lake Lusern 163 MW & 320 $\times10^6$ kWh	Wassen and Amstog 10 1MW 542 $\times10^6$ kWh	Below Jura Lake there are 12 power stations between Bern and Bionne. 3 power stations 51.3MW & 275×10^6 kWh
Po catchment Maggia and tributaries	Kraftwerke Maggia Reservoir 63×10^6 cu.m	Peccia, Cavergno, and Verhane. 202 MW and 792 $\times10^6$ kWh	On Alps Reservoir 63×10^6 cu.m 140 MW 440×10^6 kWh	Others 220 MW 1000×10^6 kWh	Kraftwerke Maggia, A.G. Lucerne have a dam 130 MW Sambu
Danube Catchment		Minor 7.5 MW 34×10^6 kWh	Inn Valley 403 MW 1340×10^6 kWh		The new schemes are promising and will facilitate interconnection with neighbouring countries.
Swiss Federal Railways		7 power stations 2 MW 70×10^6 kWh	In partnership 6 147 MW & 478 $\times10^6$ kWh		

(*Continued from page 5*)

WARSAK MULTI-PURPOSE PROJECT

and their family members. They were also provided recreational facilities including free cinema shows and indoor games.

Excellent Pak-Canadian Relations

Before concluding this description, it must be mentioned that relations between the Canadians and the Pakistanis both at the job and socially were most cordial right from the beginning.

The day's job over, they would freely mix up with each other in the Warsak Colony and at the Club in the evenings. Membership of the Club was open both to Pakistanis and the Canadians. The Club was described as one of the best in Pakistan. It had a beautiful swimming pool, grassy and concrete flood-lit tennis courts, a big dancing hall, bowling alley, billiard room, etc.

J. L. Watts
Electrical Engineer-Surveyor,
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Induction Generators and Frequency Convertors

THE INDUCTION PRINCIPLE, WHICH IS SO WIDELY employed in a.c. motors, is also applied in induction generators and frequency convertors, the operation of which can best be understood after considering how the induction motor works.

How the Revolving Flux is Produced

When a polyphase a.c. supply is connected to the distributed phases of a primary winding, as on the stator of an induction motor, each phase of the windings produces an alternating magnetic flux. Fig. 1 indicates how the fluxes due to the individual phases combine to produce a resultant magnetic flux which revolves round the primary windings at synchronous speed. Fig. 1a shows the conditions at the start of a cycle when the current in the red phase is passing through its zero value towards its positive value. At that instant the current in the B phase will have a positive value equal to 0.866 of its maximum, whilst the current in the W phase will have a negative value equal to 0.866 of maximum. Fig. 1b shows the conditions one-sixth of a cycle later, when the current in the R phase is at 0.866 of its maximum positive value, the W phase current has 0.866 of its maximum negative value, and the B phase current is zero. The remainder of the diagram in Fig. 1 show the directions of the currents and the magnetic flux at one-sixth of a cycle intervals during the cycle.

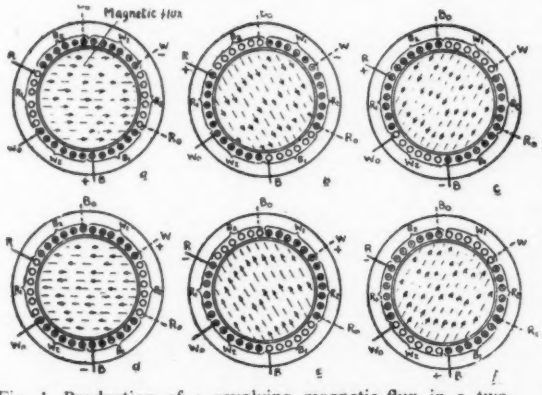

Fig. 1. Production of a revolving magnetic flux in a two-pole three-phase Induction Machine.

The resultant magnetic flux has a constant value $\frac{M}{2}$ Φ which is equal to $\frac{M}{2}$ × the maximum flux due to any one phase, where M is the number of phases. Thus, in a three-phase machine, the strength of the resultant flux is equal to $1\frac{1}{2}$ times the peak value of the flux due to one-phase of the primary windings. The flux revolves round the primary windings at synchronous speed N_s (r.p.s.) equal to the supply frequency f divided by the number of pairs of poles for which the machine is wound. In the case of a four-pole machine there are two fields, each of constant strength and at right angles to each other, which revolve at synchronous speed.

Effect of Different Rotor Speeds

Provided there are an adequate number of conductors on a squirrel-cage (secondary) winding this will automatically assume the same number of poles as the stator (primary) winding, whilst the coils on a wound rotor are always arranged to have the same number of poles as the stator winding. If the rotor is turned at the same (synchronous) speed, and in the same direction, as the revolving magnetic flux, it will move in step with the flux. Since its conductors do not then cut the revolving flux no e.m.f. will be induced in its conductors.

If the rotor turns at a lower speed N r.p.s its conductors will be cut by the flux at a speed of $N_s - N$ r.p.s. If turned at a higher speed its conductors will cut the flux at a speed of $N - N_s$ r.p.s. In either case an e.m.f. (E_2) will be induced in the rotor conductors, of value proportional to Φ $(N_s - N)$, or Φ $(N - N_s)$ case may be. The frequency of the induced rotor e.m.f will be equal to Sf, where S is the fractional slip $\frac{N_s - N}{N_s}$, or the fractional negative slip equal to

$\frac{N - N_s}{N_s}$. When the rotor circuit is closed the induced rotor (secondary) e.m.f. E_2 will cause a current I_2 to flow in the rotor windings, I_2 being equal to $\frac{E_2}{Z_2}$, where Z_2 is the impedance of the rotor windings.

Torque Production

The reaction between the induced rotor current and the revolving stator flux causes torque on the rotor. When used as a motor the fractional slip under stable conditions depends on the load on the motor. The induced secondary e.m.f. E_2 has its maximum value when the stator is energised with the rotor at standstill (100 per cent slip). If the rotor-circuit resistance is constant, as in a squirrel-cage rotor, the rotor current, I_2 will also have its maximum value at the instant of starting from rest.

However the frequency of the induced rotor e.m.f. and current then has its maximum value also, equal to the supply frequency f. The high frequency of the rotor current causes the rotor to have a high reactance and impedance, and the power factor (Cos θ_2) of the normal single-cage squirrel-cage rotor thus has its lowest value at standstill. Since the motor torque is proportional to $\Phi \times I_2 \times \text{Cos } \theta_2$ this rotor then develops less than its maximum torque at standstill.

As the rotor accelerates from rest in the direction of the revolving flux the induced rotor e.m.f. and current fall. The (slip) frequency of the rotor current also falls, with reduced impedance and increased power factor Cos θ_2. As a result the motor torque increases with the speed up to a certain maximum value, at which the rotor-circuit reactance is equal to its resistance (Cos $\theta_2 = 0.707$). As the motor continues to accelerate past the maximum-torque speed the falling rotor e.m.f. and current cause the torque to decrease, acceleration ceasing when the motor torque has fallen to a value just equal to the resistance torque of the load to which the motor is coupled. This explains the shape of the speed-torque curve (A—B—C) of the motor in Fig. 2. The mechanical power output of the motor, proportional to the product of speed and torque, is shown in curve O—D—C.

The magnetic effect of the induced current I_2 in the rotor windings, proportional to its amp-turns, opposes that of the primary (stator) current, and tends to reduce the strength of the revolving flux Φ This reduces the self-induced e.m.f. E_1 of the stator windings so that they draw from the supply mains an increased primary current, which tends to restore the value of the flux. In this way the primary current input to the stator windings automatically increases as the speed falls and the rotor current increases on increased load.

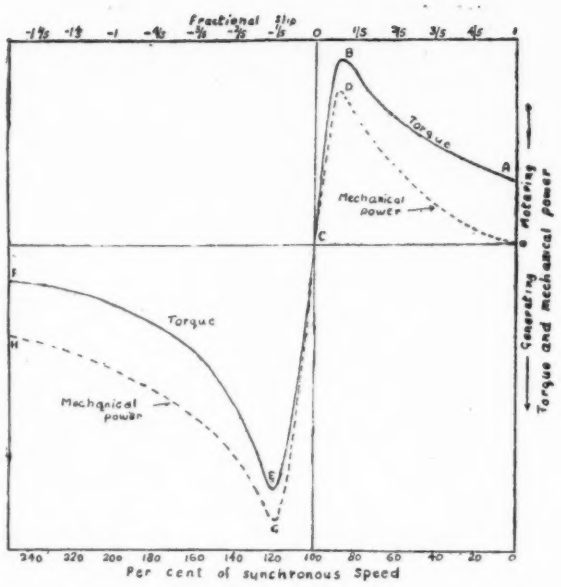

Fig. 2. Conditions in an Induction Machine when Motoring and Generating.

Graphical Representation

Fig. 3a refers to the motoring conditions, in which V_1 is the applied primary (stator) volts per phase, and E_1 the self-induced primary e.m.f. per phase. E'_2 is the equivalent value of the induced secondary (rotor) e.m.f. per phase, based on the volts per turn of the respective windings. I_0 is the no-load magnetising current, and O—F the no-load primary current, which includes a power (Watt) component A-B corresponding to friction, windage and core losses, together with small I^2R losses in the stator windings. The small component (x) is due to core losses and I^2R losses resulting from the magnetising current. For our present purposes, however, this small power component is simply treated as part of the no-load component current A-B.

The equivalent value of the induced secondary (rotor) current per phase (based on the amp-turns) is I'_2 and lags behind the induced rotor e.m.f. by the angle θ_2. The primary current of the loaded motor is thus I_1 and has the Wattless component I_0 and a component—I'_2 to compensate for demagnetising effect of the rotor current. The power factor of the input to the primary (stator) windings is thus Cos θ_1. The power component of I_1 is A-G, which includes the component D-C due to the I^2R losses in the rotor, and a component C-B due to the I^2R losses in the stator windings. The output of the motor is proportional to G-D, and its power input proportional to G-A; thus its efficiency is equal to $\frac{\text{G-D}}{\text{G-A}}$.

Operation of an Induction Generator

If the primary windings are energised from the supply mains, and the rotor is then driven at synchronous speed in the direction of the revolving magnetic flux, the primary windings will then draw from the mains the Wattless magnetising current I_0 and the small power component x equivalent to the core losses and the minor I^2R losses due to the magnetising current. The rotor can then be driven by merely applying sufficient mechanical power to overcome its friction and windage, approximately proportional to (A-B) minus x.

If the rotor is then driven at more than synchronous speed, i.e. with negative fractional slip $\frac{N - N_S}{N_S}$, the induced rotor e.m.f.. will be reversed in phase, as in Fig. 3b since the secondary (rotor) conductors now cut the revolving flux in the opposite direction. The rotor then exerts a negative (braking) torque, proportional to $\Phi \times I_2 \times \text{Cos } \Theta_2$, and mechanical power would have to be applied to the rotor to keep it turning at more than synchronous speed. In Fig. 3b we have the same notation as in Fig. 3a. I_1 is the primary (stator) current. Since this is more than a quarter of a cycle out of phase with the applied voltage V_1 the machine acts as a generator and returns power to the supply mains, equal to $V_1 \times I_1 \times \text{Cos}\,\Theta_1$ per phase, and thus proportional to the power component A-G. The mechanical power which must be applied to the rotor is proportional to D-G; thus the efficiency of the generator may be taken as equal to $\frac{A\text{-}G}{G\text{-}D}$.

The induced rotor e.m.f. E_2 is proportional to the fractional slip (which is negative), and increases on increased speed; causing the braking torque to rise to a certain maximum value E, as in Fig. 2. However at higher speeds the increasing rotor reactance, and falling rotor-circuit power factor, cause the torque to fall. This regenerative braking effect is useful in that it tends to limit the rise of speed above synchronous value in the event of an induction motor being driven by its load, as might occur with a motor driving a vehicle or the hoisting motion of a crane. But if the driving torque exceeds the maximum braking torque the machine will become unstable and its speed will continue to increase. However the speed at which the maximum torque occurs, and thus the power which can be absorbed without instability, can be increased by connecting resistors in the rotor circuit to raise its power factor.

Uses of an Induction Generator

An induction motor of the squirrel-cage or slip-ring type can thus be used as an induction generator, giving an electrical output from a mechanical input,

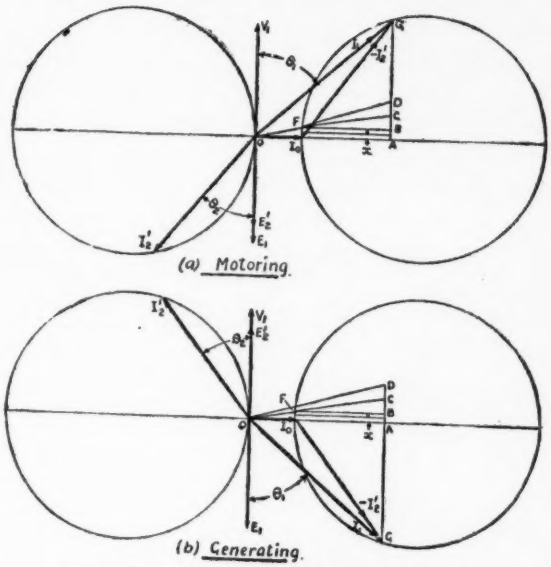

Fig. 3. Current Locus of Induction Machine.

if the stator is connected to a polyphase supply. For low slip values the electrical power output is almost proportional to the negative slip. Although its efficiency is not very high it is a robust machine, and can be operated in parallel with other generators without hunting. Slight speed variations of the prime mover are of little importance.

It may be driven by a steam engine fed from waste heat plant, or from exhaust steam from engines, or as an alternative to a pass-out or back-pressure turbo-alternator where large quantities of process steam are used. It also has uses at a hydro-electric station. It can be operated as a generator by water flowing from a high level to a lower one during periods of peak load on the mains, and can be used as a motor to pump water back from the low level to the higher one during periods of low load, thus tending to even out the demand on the supply system.

Self-Excited Induction Generator

It is possible also to use an induction generator on an isolated system by using capacitors to provide the magnetising current, since the latter lags behind the applied voltage by a quarter of a cycle, while the capacitor current leads by a quarter of a cycle. The frequency of the generated currents on no load will then be approximately equal to $\frac{1}{2\pi\sqrt{LC}}$ i.e. the resonant frequency between the capacitance and the inductance of the primary windings.

The induction generator is quite suitable for supplying a unity power factor load. However if the fall of terminal voltage from no load to full load is to be

reasonably small it is necessary that the magnetic flux density in the machine shall have a high (saturation) value on no load, or that a saturated reactor be connected in parallel with the primary windings and capacitor.

Induction Frequeney Convertor

The induction machine is widely used as a frequency convertor, mainly to supply power at high frequency to high cycle motors from supply mains of normal frequency. The required output may be from 75 to 450 cycles. A normal induction motor, running at slightly less than its synchronous speed, may be coupled to the induction generator, as in Fig. 4. The latter machine has the same construction as a slip-ring induction motor. The primary windings of the generator may be fitted in the stator slots, and they

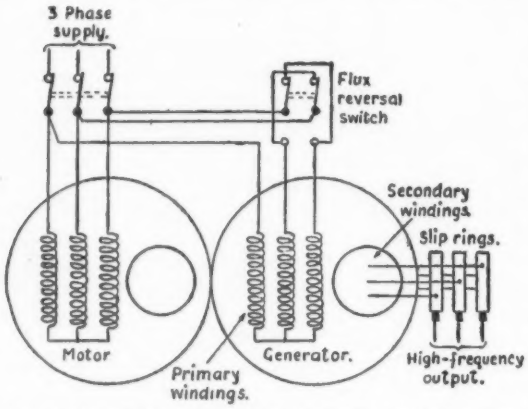

Fig. 4. Connections of a Dual-frequency Induction Frequency-Changer.

create magnetic flux which revolves round the primary winding at synchronous speed N_s (r.p.s.) equal to $\frac{f}{P_2}$ where f is the supply frequency and P_2 the number of pairs of poles in the primary windings. With the rotor at rest the flux cuts the rotor (secondary) conductors at $\frac{f}{P_2}$ r.p.s. to generate e.m.f. of supply frequency f in the rotor windings. Under these conditions the generator acts as a static transformer having a rather high magnetising current and leakage flux.

If the driving motor has P_1 pairs of poles its no-load speed will be almost equal to its synchronous speed N'_s and will be equal to $\frac{f}{P_1}$ r.p.s. If the motor drove the generator at N'_s r.p.s. in the direction of the revolving flux of the generator the flux would cut the rotor conductors of the generator at $N'_s - N_s$ r.p.s. The frequency of the generator e.m.f. in the rotor conductors would then be equal to $P_2(N'_s - N_s)$ cycles per second. With a two-pole motor on a 60 cycle supply N'_s would be 60 r.p.s. If the generator had six pairs of poles N_s would be 10 r.p.s. on the same supply. Under the conditions mentioned the output available from the slip rings of the generator would be at 300 cycles per second. A two-pole motor fed from the slip rings would then have a synchronous speed of 300 r.p.s., or 18,000 r.p.m.

If the rotation of the revolving flux of the generator was then reversed by the double-pole two-way switch shown in Fig. 4 the rotor conductors would then be cut at $N'_s + N_s$ r.p.s., giving an output frequency of $P_2(N'_s + N_s)$, equal to 420 cycles in the case discussed.

Power and Output Voltage

The output of the convertor is partly due to transformer action and partly to conversion of mechanical to electrical power. Thus the horse power rating of the motor may be less than that of the generator. In some convertors the a.c. supply is applied to the slip rings and the output taken from the stator windings. In this case the rotor windings are used as the primary and the stator windings as the secondary, the principle being the same.

The e.m.f. generated in the secondary windings of the generator is proportional to the strength of the revolving magnetic flux and the relative speed of the conductors with respect to the flux, and thus varies in the same way as the output frequency if the flux has a constant value. There will be a slight fall of voltage output in the secondary windings on load, owing to the impedance of these windings. The driving motor will run at slightly less than its synchronous speed on load, which will slightly reduce the output voltage and frequency, and there will also be inherent slip in the supplied high-frequency motor on load. However the latter may run at about 95 per cent of its synchronous speed on load.

Since the generated voltage in the convertor is almost proportional to the frequency, both will fall when the switch is used to cause the revolving flux of the generator to turn in the same direction as its rotor, instead of in the opposite direction. However this will have little effect on the peak torque of the supplied high-frequency motor, which is practically proportional to $\left[\frac{\text{voltage}}{\text{frequency}}\right]^2$ The speed of the high-frequency motor is practically proportional to the frequency, but its full-load torque is practically unaffected by simultaneous change of applied voltage and frequency in the same ratio. Thus the horse-power rating of the high-frequency motor is practically proportional to the frequency output of the convertor.

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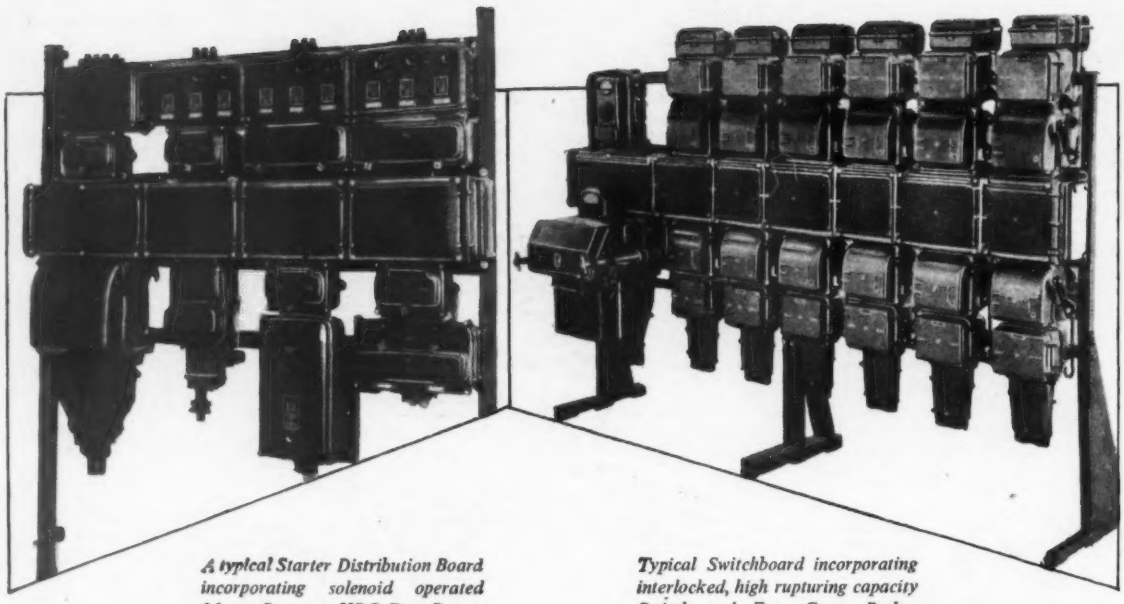

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Establishment of Zonal Grids

General Principles and Proposals for Northern Grid

EVERY LARGE POWER SYSTEM IS DESIGNED FOR working with some stand-by power plant so that the demand on the system can continue to be met in the event of any accident to the generating plant. The standard practice is to treat the largest unit in a power house or a set of inter-linked power houses, as stand-by and limit the peak load on the system to the capacity of the remaining generating units. If there are two power houses, working independently of each other, a stand-by unit has to be maintained in each. If a number of generating stations are inter-linked and are run as an integrated system, it is not necessary to keep stand-by plant in each station; in that case the largest unit in the integrated system is only kept as stand-by. The inter-linking of a number of generating stations, therefore, will increase the peak load capacity of the system by eliminating stand-by power plant in all the Power Houses except the one with the largest unit.

During the last few years, a number of large hydro and steam power stations have been set up in all parts of the country. Most of the projects have been the venture of individual States/Boards, undertaken to meet the demands of the respective States, though, in some cases, projects of extraordinarily large magnitude have been undertaken and set up for meeting the requirements of two or more states such as the Bhakra Nangal Power Project, the Chambal Valley Project, Damodar Valley Project, etc. etc.

Every project has its own peculiarities in the matter of power potential and the demand experienced on the system. So far as steam power systems are concerned, there is hardly any variation in the power potential; but in the case of Hydro Projects, there are often vast variations in the power potential of the system, depending upon the objectives of the Project, the water releases from the storage reservoir, the conditions of water flow in the river and the variations therein. If a constant water discharge is maintained, there is no difficulty about power generation which will remain constant; but in Hydro Projects, at least in India, this is not the case with most of them. Even after providing large storage reservoirs, a sufficient constant flow may not be available all the year round and in all the years, on account of large unexpected variations in the river discharges. Thus the power generation will not remain constant. Further, in the case of power houses working with medium and high head reservoirs, the output of each machine goes down as the working head goes on falling with the depletion of the storage reservoir, during the period of low river discharge and the power generation is also reduced correspondingly. In some cases, the variations may be very considerable. For example, in the case of Bhakra Power Plant, the output of each machine being installed in the Left/Right Bank Power House, will be reduced from a figure of 90/120 MW, available at the highest head, to a figure of 53/70 MW at the lowest head experienced when the water level in the storage reservoir falls to the dead storage level every year.

In some multi-purpose projects, the water releases are governed by interests of schemes other than the power scheme alone, such as irrigation, navigation etc. In such cases, the variations in the power potential may be still greater, resulting in a very big gap between the maximum and the minimum output of the power systems. The example of Bhakra again is very interesting in this respect. The water releases from the Bhakra Reservoir are regulated primarily according to irrigation requirements; the releases vary from a maximum of 24,000 cusecs to a minimum of 6,800 cusecs and accordingly the power potential of the water being discharged below the Dam, varies from a maximum of about 800 MW to a minimum of 133 MW at 100 percent load factor. In order to increase the power potential of the project, some modifications have been made in the canal system whereby a part of the requirements of the Bhakra canals during certain parts of the year, will be met by the water of Rivers Beas and Ravi and an equivalent amount of water will be conserved in the Bhakra Reservoir for being released during the short water period. By this arrangement, the firm power capacity of the project has been increased to 267 MW at 100 per cent load factor. Though the general pattern of water discharges

from various storage reservoirs may not be the same as in Bhakra but in every multi-purpose project, having irrigation as one of its objectives, the water discharges will normally not be constant and will vary during the various parts and seasons of the year, thereby resulting in a varying power output of the system. It is quite likely that when the power available from water releases in one project is at its lowest, it may be the highest or midway between the highest and the lowest, in another project. If two such power systems are linked up, the combination will obviously have a much greater firm power capacity than the sum of the lowest firm capacities of the two systems. In some cases this may turn out to be the biggest advantage of inter-linking two or more power systems.

Further, the annual load curve on all the power systems is generally not identical. Every system has its own peculiarities and the demands experienced on each will vary from season to season depending upon the pattern of Industries, the types of loads, main occupation of the population etc. etc. Every system may have its seasonal load with widely different working periods during the year. For example, a very substantial irrigation pumping load in Punjab is off during the rainy season i.e. July, August and September. In a State served by another system there may be some seasonal loads which work during this season. If the two systems during a particular period of year can be used in the areas served by another power system, and thereby the peak load capacity of the integrated system can be increased considerably.

Yet another very important advantage would be the adjustment in the matter of daily load figures. The periods of peak load on one system may differ from those of another system on account of different working hours of different kinds of industrial, agricultural, domestic and commercial loads. Very rarely will the peaks on two systems occur at the same time, mostly they will occur at different periods of the day. There is often a substantial margin between the average load and peak load and normally the peak lasts for a short duration. The variation will easily be 10% and may be often more in most cases. If two systems are linked together and run in parallel, the peaks of one system can be adjusted against the off-peaks of the other system and the peak capacity of the combined system can easily be increased by about 10 percent of the capacity of one system without increasing the generating capacity.

The integration of a number of power systems into one through a zonal grid would necessarily mean grouping together of generating station of low, medium and high head as well as steam plants. The low and medium head power houses are generally located on canals or at the places where canals take off from dams. In such cases the water flow passing through or past the power houses is usually constant and there are some definite periods daily when the load is less than the power potential of the flow, and the result is a clear loss of power potential. In an integrated system, all such stations running on constant water flow, can be utilised to the maximum limit by using them as base load stations and running them at practically 100 per cent load factor; the high head stations can be reserved for taking, as far as possible, only peaks on the system. In a combination of high and low head stations, such an arrangement could result in increasing the peak load capacity of the system with the same overall total water discharge through all the stations.

In addition to the above advantages, the integration of two or more power systems will increase the operational efficiency of the integrated system. Accidents in running machines and big projects, though very rare, are unavoidable and if two or more systems are integrated, the difficulties experienced by any one system on account of an accident to the generating system, will be reduced very considerably by the transfer of load to the other system; even under the worst circumstances, the continuity of supply to the essential services can be ensured without much difficulty.

Integration of Power Systems

The inter-linking of power systems can broadly be of two types. One would be to integrate the power systems as they are, by means of extra high tension lines. Such an integration will have all the advantages pointed out in the foregoing paragraph but a better arrangement would be to link them through a large Central Power Station. Such a power station will mostly have to be a steam or an atomic station of capacity not below 500 MW to start with and having a provision for extension upto 1000 MW or even more. Exchange of power with such a central station will be more easily controllable and will also be more economical by reducing transmission losses. Further such a power station, if provided in an individual project will not act as a base load and will in most cases act as a peaking station but if it is provided as a part of a number of power systems, it will more or less be a base load station with a very high annual load factor which will very considerably improve the economics of such a power station. While considering the setting up of atomic power stations for meeting the demand of individual states as a part of Hydro systems, the results have not been encouraging because in a hydro system, such a station would mostly be used for firming up the power of the hydro system and not as a base load. When such a station is used as part of a number of hydro systems, though in effect it will firm up the power of individual power systems, the net result will be that it will have a very high load factor which would increase the economics of power generation and justify such a project.

Northern Grid

Selection of site for such a central generating station for the purpose of integrating the power systems of 3 or 4 States or Boards will not be a difficult problem. Northern Grid can be created by linking the power systems of Bhakra Nangal Power Project (serving Punjab including J & K and Himachal Pradesh, Northern Rajasthan and Delhi), Chambal Valley Project (serving Eastern Rajasthan and Western Madhya Pradesh), Ganga Hydro Grid (serving Western and South Western U.P.), the Sarda Canal Power system (serving Central and Northern U.P.) and the steam stations of Kanpur, Agra, Delhi and Chandausi. An atomic Power Station located at Faridabad on Palwal which are about 20 and 40 miles respectively towards South of Delhi and which are located near the Boundaries of U.P., Punjab, and Rajasthan and not far away from those of Madhya Pradesh, can serve as a Central Power Station of the Northern Grid and will provide an ideal control centre for the power systems of Punjab, Delhi, Rajasthan, U.P. and Madhya Pradesh. Its nearness to Delhi, will ensure continuity of power supply to the Capital which has a fairly large concentrated load and with very small, practically negligible, losses. A power station located as suggested above would be practically equi-distant—nearly 250 miles—from the power houses of the Bhakra Nangal Project, the Chambal Valley Project, the Sarda Canal Project and Kanpur whereas it would be nearer from the power systems to Ganga Hydro Grid, Delhi and Agra. This situation would practically be ideal and being near to River Jamuna, the water problem can also be solved without much difficulty.

The transmission lines from the power stations of the projects mentioned above, have already been erected in many cases and in most of the cases, they extend far out towards the proposed site of central station; the farthest points of these transmission systems will be much nearer to the site of the central power station. The 220 kV transmission line of the Bhakra Nangal system is already at Delhi and a new line upto Faridabad has been provided in the Third Plan. The Ganga Grid transmission system across the river will be about 50 to 60 miles. The nearest terminals of the Chambal Valley and Sarda Canal Power Systems may be about 150 miles.

The selection of a suitable transmission voltage will be another important problem. Since large blocks of power may ultimately be exchanged through these lines, it would appear desirable to choose an operating voltage of the order of 350 kV. Alternatively, the system may be designed for ultimate operation at 350 kV but in the initial stages it may be operated at 220 kV. The change-over from 220 kV to 350 kV can take place at a later date when the load so demands. The 220 kV switch gear and transformers would easily be utilised at that stage in any other project operating at 220 kV and will not present any difficulty. Such an experiment has already been tried quite successfully on the Bhakra Nangal Power Project. The main transmission line from Nangal to Delhi was designed for 220 kV but the insulation was provided for and the line was operated at 132 kV. Now it is being converted to 220 kV along with the connected grid sub-stations. The conversion is being carried out without interrupting the supply by the staff which has received Hot Line Training.

Operational Control

The design, construction and operational control of a Zonal Grid can obviously be not entrusted to any individual State Electricity Board. It would be best to have a Control Board consisting of representatives of the various State Electricity Boards, in which the C. W. & P. C. should also be associated. It would probably be advantageous if such a Board is constituted with the Chairman, C. W. & P. C., if he is a Power Engineer or the Hydro Electric Member (of the Power Wing) as its Chairman. The planning and designing of the Grid transmission lines and the central power station, if any, should be the responsibility of this Board. In case, a central power station is provided, the transmission lines connecting it with the power systems of the individual States should be constructed, according to the design finalised by the Control Board, and maintained by the States concerned at their own cost. In case or so long as a central power station is not provided, the route of the inter-linking transmission lines, their capacity, operating voltage and the necessary protection, etc. should be settled by the Control Board. The capital cost of the lines located in each State should be borne by the State Electricity Board concerned and so should be their maintenance. So far as the construction is concerned, this could be done by the respective State Electricity Boards in their areas or by mutual agreement, could be entrusted to any one of the participating State Electricity Boards depending upon its capabilities for handling such projects. Whenever construction of transmission lines and substations within the boundary of one State is entrusted to another State Electricity Board, the latter will have to be assisted by the Electricity Board and the Government of the State concerned in the matter of land acquisition and other facilities such as accommodation, water supply arrangements, local labour, etc. Alternatively, a central organisation could be set up under the Control Board for the construction and maintenance of the inter-linking transmission lines and the Central Power Station by drawing, on deputation, suitable personnel from the respective State Electricity Boards who would have sufficient trained staff for such jobs.

A detailed arrangement shall have to be worked out and agreed to between the participating State

Electricity Boards for the exchange of power between the integrated power systems and the Central Generating station, the points and method of metering, the rate chargeable, method of payment, etc. If there is a central power station, it would also be necessary to lay down the share of each participating State Electricity Board out of its generating capacity. A suitable Grid tariff will have to be fixed for the purchase of power from the central power station, keeping in view that it should ensure enough revenues to the common pool system to meet all the operational expenses. The capital cost of the central station should be shared amongst the participating State Electricity Boards in the ratio of their share of generating capacity and they should be responsible for the payment of interest on and repayment of their share of the capital expenditure. In that case, the rate for grid supply should be based on the depreciation charges and the charges for operation and maintenance. The power drawn by each participating State Electricity Board will have to be measured at the Central Power Station and paid for to the common pool at this rate. In case, power is drawn by two or more participating Boards from power station through a common transmission line, further adjustment among such State Electricity Boards will be necessary, depending upon the point at which power is tapped or received by each Board from the common transmission line and the losses upto that point. If a line is the property of one State Electricity Board, then the other State Electricity Board drawing power from this line, shall have to compensate the owner Board towards the operating expenses of the line including interest, depreciation and maintenance, in addition to the grid rate plus losses for transmission and transformation. Such a tariff can be either a flat unit rate or a two-part tariff; however keeping in view the fact that the common pool system is meant for frequent power exchanges, it would be difficult to adopt a two part tariff which may, at times, work out harshly to some of the participating State Electricity Boards and may even present practical difficulties in metering and billing. It would, therefore, be desirable to have a flat rate tariff on a unit charge basis.

Whenever power is fed into the central generating station by the power system of one of the participating State Electricity Boards, for use by other Boards, the same shall have to be paid for by the common pool at the grid tariff of the power system of the concerned State, fixed after taking into consideration such points as the cost of generating of the system, the distance from the generating station, the transmission losses and other expenses involved upto the central station. On account of the considerations mentioned in the foregoing paragraph, such a tariff should be a flat rate tariff on unit basis.

The position would be a little more difficult if a central power station is not provided. In that case, a basic question for consideration and decision would be whether the exchange of power between the various power systems of the participating State Electricity Boards should be at one uniform rate irrespective of the fact that the cost of generation and transmission involved is different on different power systems of the grid, or whether it should be linked up with the cost of generation and transmission on each system. A lot can be said in favour of and against each of the two proposals. A system whose cost is lower, will naturally grudge to purchase power whenever needed by it, at a rate higher than its own cost of that at which it sells to other systems. The demand in such a case for the same rate of sale or purchase would be quite reasonable and forceful; it would apparently be unreasonable to force such a State Electricity Board to charge lower rate when it sells power and to pay a higher rate when it purchases power. On the other hand, a system whose cost is higher, can argue, and with some justification, that when it sells power to other systems, it must not be a losing proposition, though sale on "no loss no profit" basis may not be grudged. Such a question would particularly arise when a system with steam generation is integrated into a hydro system. Then again, fixing different rates for sale and purchase of power by the same system would not appear to be a good and practical solution and would create complications in working, though, it may, to some extent, be logical and reasonable. With a view to meeting all the above points and safeguarding the interests of the integrating power systems, the proper solution would appear to be to fix one uniform rate for the exchange of power among all the integrating systems on the basis of the rates of that system in which the costs are the highest. That system will have no grudge because it does not loose anything either in the sale of power or in the purchase of power from another system at the same rate as it would cost the same amount to it, if it were to generate this power itself. So far as the other systems are concerned, they will undoubtedly be paying more than their own cost when they purchase power but this loss will be made up when they sell power to other system at the higher rate; accordingly they will have no cause to grudge in general. Such exchanges of power might result in small losses or gains ultimately but these would be worthwhile foregoing in view of the overall simplicity of working of this arrangement. It may be mentioned that chances of purchase of power by hydro systems from steam stations are much less and the quantum sold will mostly exceed the quantum purchased. Adoption of this system of charge would also be preferable for the purchase of power when a central generating station is provided.

Sharing of Increased Capacity

As outlined in the foregoing paragraphs, the over-

all capacity of all the integrated power systems will increase as a result of the following:

(a) Adjustments due to water discharges;

(b) Elimination of standby in various systems;

(c) Adjustment of load sharing between low and high head stations;

(d) Adjustments due to annual load variation and seasonal loads; and

(e) Adjustments on account of daily peaks.

It would naturally be necessary to work out a method by which the increase in the system capacity is to be shared among the various participating power systems. Different principles and methods will have to be applied for the allocation of increased capacities resulting from each of the five items mentioned above.

The increase in capacity under item (a) can be allocated as under:—

Suppose there are two power systems each having a firm capacity of A & B MW at 100 percent load factor depending upon the lowest water releases or the lowest head available and if, as a result of integration, the peak load capacity increases by C MW, it would be shared by the two systems in the ratio of their firm capacities. The share of first and second systems would be $AC/(B+C)$ and $BC/(A+B)$. The increase resulting from the integration of more than two power systems will also be shared according to the above principles. The principle will also apply for sharing the increase in capacity resulting under item (c).

The increase in the system capacity under item (b), resulting from the elimination of standby units, can be allocated as under:—

Let there be 5 power systems which are being integrated and that the standby capacity, based on the largest unit in each, is A, B, C, D & E MW respectively with a total of F MW. If A is the largest unit among them, the increase in the system capacity would be the sum of B, C, D & E, say G MW. The share of the first system whose standby capacity was A MW, would be AG/F; that of the second system would be BG/F, and so on.

It would be rather difficult to allocate the increase in system capacity due to the balancing of the fluctuations taking place in the annual and daily load figures. There need not be any allocation of this increase though every system will gain something and it would be quite sufficient if the exchange of power is accounted for in the financial working at the grid rate.

Development of Zonal Grids

The entire country is facing an acute power shortage and this situation has already been the cause of impeding industrial development. The control on the expenditure on power projects in the Second Plan has displayed the disadvantages and the harm it has done, quite vividly. It is, however, encouraging to note that in the Third Plan it is proposed to increase the installed capacity in the country from 5.8 to 11.8 million kW. The installation of this additional capacity is likely to take a little longer since heavy machinery has mostly to come from outside. The immediate requirements can be met partly by inter-linking the power systems to be brought under a zonal grid. The ultimate planning should provide for such inter-linking through a Central generating station, the transmission lines which can be completed mostly with the help of indigenous production, should be provided immediately.

So far as the central generating stations are concerned, it would be very desirable to adopt, as far as possible, a uniform design for all such stations to be erected under the various Zonal grids. The size of the generating units should be 125 MW each and the installation should be so planned that at least one such unit is added every year, unless, of course, the load development in any particular region demands a quicker construction programme. The adoption of a uniform design and size for the units to be installed in the central generating stations of the zonal grids would ultimately help the integration of Zonal Grids into a National Grid.

(Continued from page 8)

WARSAK POWER HOUSE

Kabul river will carry about 5,000 cusecs which will give ample supply for the operation of one turbine for all the 24 hours. The power now generated has been grided up with the Main Power Grid through Wah to meet demands over a large area in West Pakistan. The final installed capacity of the power house is 2,40,000 kW and the presently installed capacity is 1,60,000 kW. This may be compared with the proposed installed capacity of Sui Gas Multan Power House which is 1,30,000 kW. The installed capacity of hydel power house at Rasul is 22,000 kW. The Dominion Engineering Co. of Canada supplied the design and plans of draft tubes and spiral casings as well as the steel parts. The Canadian Allis Chalmers have supplied the penstocks material and drawings. The suppliers associated with the machinery to be used in the power house are Canadian Vickers Ltd., John Hepburn Ltd., Blaw Knox Company. The Canadian Commercial Corporation supplied the generators, transformers, Switch gear and other miscellaneous equipment.

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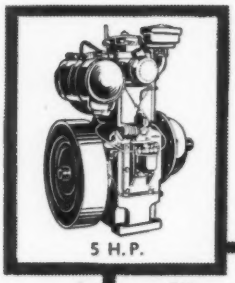
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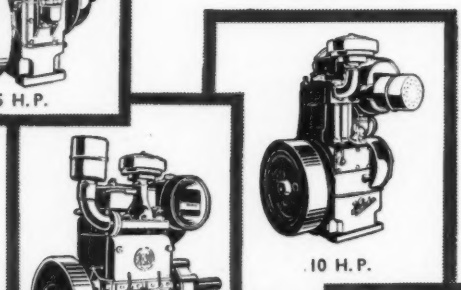
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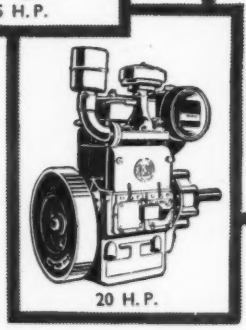
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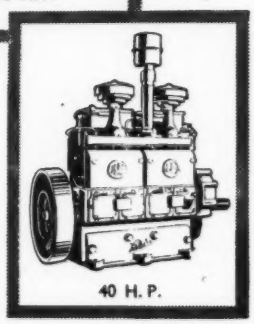
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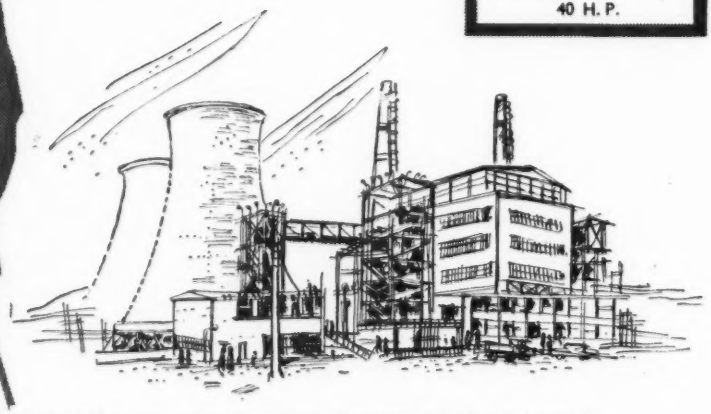

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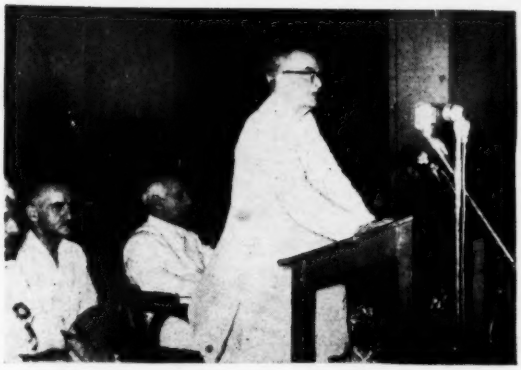
Central Board of Irrigation and Power

Thirtyfirst Annual Research Session

THE 31ST ANNUAL RESEARCH SESSION OF THE Central Board of Irrigation and Power was held at Calcutta from 5th to 8th June, 1961 preceded by meeting of six Sub-Committees and followed by a study tour covering important projects like Mayurakshi, Damodar Valley Corporation, Durgapur Steel Works, etc.

Dr. B. C. Roy, Chief Minister of West Bengal inaugurated the Session on 5th June, 1961. Shri A. K. Bhaumik, Chief Electrical Engineer, West Bengal welcomed the Chief Guest, Dr. Roy, Shri Bhatia, the President of the Central Board of Irrigation and Power and the delegates to the Session. Shri H. R. Bhatia in his Presidential address welcomed the delegates and presented a brief review of the work at the various research stations during the year. He pointed out that attention to power research was not being given to the extent required, in spite of a large programme of power development in the country. He informed that a grant of Rs. 30 lakhs in the first



Dr. B. C. Roy inaugurating the Session.

IT IS OBVIOUS THAT ENGINEERING IS AS OLD as life itself. Some of the tiniest creatures have shown baffling skill in making their cells and shelter. We have been fascinated by their beauty, form, strength and utility. There is a lot of science of strategy in the warrens that the rabbits build; the perfect lay-out in the plan even of the ant-hill; and a great deal of organisation and systematic town planning, and even temperature control, in the beavers. If the little beaver, perhaps, made the first artificial reservoir by building dams, there is always something that man could learn from admiring the creative instinct of these creatures. Yet, there is something which man has been slow in learning, that is, the utilisation of entirely locally available material in construction and above all, adherence to a strict time schedule against heavy odds.

Man's own appearance in this planet puts him straight into a life and death struggle with nature. The story of human civilisation is the story of our capacity to build and our history is written mostly on the face of such structures. Our earliest known relics of the high civilisation of Mohenjodaro and Harappa give ample evidence of the existence of a well-developed science of public health engineering, town planning and house building. Later excavations have even revealed what could be described as provision for irrigation and even control of floods and soil erosion. That our famous temples on the sea beaches are still there, bear testimony to the knowledge of science of tidal waves that our ancestors had acquired. All these were perfect scientific knowledge and not mere instinct or religious faith as some people think to explain away these facts. Their scientific knowledge of soils, weather forecast, geometric patterns, building material have stood the supreme test of time. Later architects showed great skill in design of stupas, caves, temples, forts and other monuments. Today unfortunately at a stage where we have lost all link with the past and are not fully in the grip of the present, we are decades behind modern science; we have been learning from other peoples, other man's text-books, without very much caring to apply this knowledge to the local conditions. It is true that a few years independence has given an opportunity to the youngmen and engineer to build with their own hand, with their own material and design. But we have to make for loss of these 200 years of inactivity and isolation.

—**Dr. B. C. Roy,** *Chief Minister, West Bengal, dur'ng his inaugural address.*

Mr. H. R. Bhatia delivering the presidential address.

instance for research on power problems has been recommended to the Planning Commission for undertaking such work in the various State Electricity Boards. Shri Bhatia mentioned that efforts for bringing the professors and lecturers engaged in post graduate courses in Engineering Colleges and Universities are being made to associate themselves with advanced research pursued in the various Irrigation research stations. Mention was made of an interesting study that had been taken up on volute siphons availing the opportunity offered by the prospective submergence of the Hirebhasagar Dam.

Continuing, he compared the amount of attention that was being paid by the Electricity Council in England on power research. While they had spent to the end of March, 1960, £2.2 million on research in addition to sums for research on normal day to day operation of the power stations and transmission and distribution systems, this country has yet to start such efforts, and for this the Electricity Boards of this country should take immediate steps to establish research units without any further loss of time. Further he enumerated some of the following important problems on which research should be undertaken in this country by the Electricity Boards, viz.: developments in the transformer oils for its reuse without waste, incidence of lightning on power systems; conductor vibrations on Transmission lines, stresses in Transmission Towers under various conditions of wind and temperature, etc. Shri Bhatia emphasized the need for collection of data regarding losses in transmission and distribution of power to prune the system for efficient output. Illustrating the advanced research and the attention paid in some of the important countries like U.S.S.R. and also achievement of scientists like Edison, he emphasized on the Research workers sparing no pains in solving many of the problems that needed solution, in the development of our country.

Dr. B. C. Roy inaugurating the session referred to the problem of drainage that is facing Calcutta and its hinterland and said that it was a perpetual source of trouble for those who were confronted with the maintenance of the city of Calcutta and its drainage system. He said that even as the beavers—mere animals—resort to twigs and stones for making small dams across natural water courses, man should utilise entirely locally available material on time schedule for construction of structures, instead of depending too much on foreign sources. He also observed that the need of the day was for a larger team of practical general purpose engineers, overseers, skilled

A vieiw of the audience at the time of inauguration.

hands and the handpicked specialists should be used only to plan and guide the work. He emphasized the need for a positive and creative outlook. Further he advised that every engineer should take interest in the works he is in charge of and be proud of his assignment. Without a liberal application of common sense and appreciation for the people's immediate needs, any efforts put forth would be of no avail.

Referring to the Ganga Barrage project he said that it was a question of life and death to Calcutta and its hinterland which get water supply only from the Ganges and it is this that keeps the port. Lack of fresh water has been continually experienced over the years with increasing advancement of salinity in the Hooghly. The 1st and 3rd day of the Session which was devoted to paper discussions, were held at Mahajati Sadan, Calcutta and the 2nd day's proceedings were held at Haringatta Research Station where the delegates went round the models. The Hon'ble Minister for Irrigation and Waterways, Shri Ajoy Kumar Mukherjee took keen interest in the deliberations of the Session.

The 38 papers that were discussed during the Session covered theory and practice of model experiments, hydraulic works, power problems. Soil Science and Soil Mechanics, design of channels, irrigation and navigation practices and materials of construction which were of immediate importance to the River Valley Projects in particular and to the development of new techniques in the field of Engineering technology. The deliberations stressed the need for closer collaboration between the designers of engineering structures and Research workers. One of the points that emerged out of the discussions was for screening out mica from micaceous sand by a belt conveyor system whereby cost could be reduced. In the design and lay-out of power system the State Electricity Boards should keep in mind the continuing need of expanding power system and aim at standardization with a view to helping the indigenous electrical industry to economise cost of production. Many useful suggestions for further research work on different aspects also emerged out of the discussions of the papers, both in the applied as well as basic research work.

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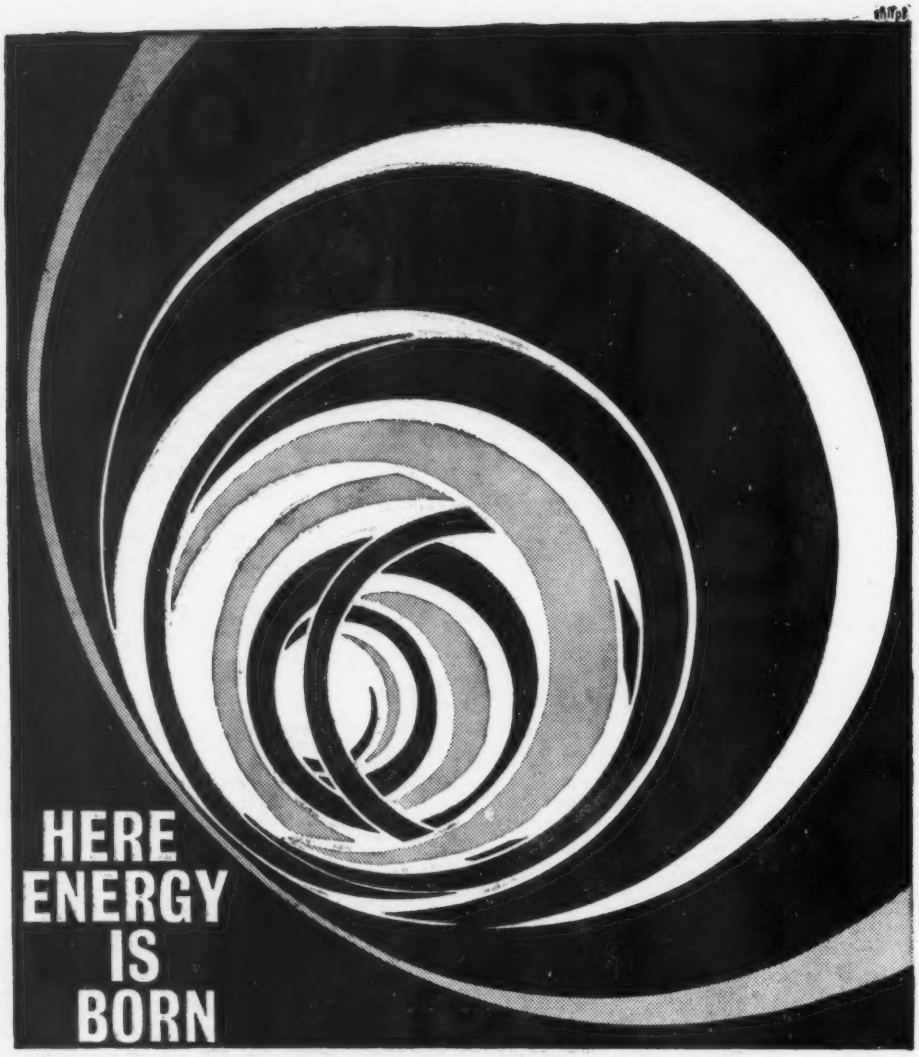

Through these strong steel walls of the penstocks water rushes down to the powerhouse gaining the velocity and kinetic energy required to whirl the turbines and generate electricity. The power that emerges from the hydro electric projects is thus born in the circular walls of these penstocks. IHP is supplying these penstocks to almost all major hydro-electric projects of India today.

Every day tons of vital penstocks of various diametres and thicknesses roll off the lines of the IHP factory at Hadapsar assuring a continuous supply to meet the requirements of the various hydro-electric projects planned in the 2nd & 3rd Five Year Plans.

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Neriamangalam Hydro-Electric Project

SITUATED ON THE RIGHT BANK OF PERIYAR RIVER, just below its confluence at Panamkutty with Muthirapuzha river, the Neriamangalam Power Station with an installed capacity of 45,000 kW, was inaugurated by Dr. S. Radhakrishnan, Vice-President of India, on April 12, 1961. This project will partly meet the growing demand for power in the Kerala State. The water from the Muthirapuzha river is diverted by means of a Weir at Kallarkutty and conveyed via a tunnel, 11,140 ft. long ending in a Surge shaft, from whence a low pressure pipe conducts the water to three penstocks feeding three turbines. The normal gross head available for power generation is 650 ft.

The hydraulic turbines are of the vertical Francis reaction type supplied by Messrs. Charmilles, Geneva (Switzerland), represented in India by Kaycee Limited. The turbines are equipped with oil pressure type governors of modern design with high sensitivity which, at the same time, limits the pressure rise in penstocks to the optimum value.

The entire electrical equipment comprising three generators, transformers, indoor and outdoor switchgear, control and power cables, etc., has been supplied by the well-known Swiss Manufacturers, Messrs. Brown Boveri & Company Limited, Baden (Switzerland), who are represented in India by Messrs. Voltas Limited.

The three generators are of the vertical, conventional design with thrust bearing located above the rotor. Each machine is capable of delivering continuously 15,000 kW at 0.85 p.f. with a normal speed of 600 r.p.m. and generating voltage of 11 kV. Damper windings have also been provided to improve the stability of the machines.

The generators are equipped with high capacity, quick acting voltage regulators, the working principle of which is based on a balance between the mechanical spring tension and the electrical torque on a moving system.

Two special features of the automatic voltage regulator are worth special mention:

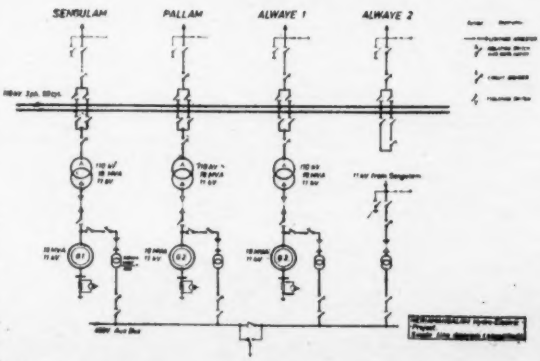
(a) The regulator is equipped for remote control of the spring tension. The working range of the regulator can be shifted to lower values by decreasing the spring tension from the control room, without changing the position of the adjusting resistor which is fixed for the normal operating voltage. This feature is extremely useful while charging of an unloaded transmission line.

(b) The regulator is also equipped for negative impulse excitation whereby the polarity of the main exciter field is reversed, resulting in a very quick decrease of the generator voltage. The negative impulse excitation can be arranged to come into operation at a preset percentage of the voltage. As soon as the generator voltage falls back to the optimum value, the regulator goes back into normal service. This feature has been found very useful when a lightly loaded line gets discharged at the other end which would normally result in very high over-voltages.

In consonance with modern practice, block system has been adopted for this Power Station with each generator connected to its own main transformer and the common busbars located on the high voltage side of the transformers. Each machine has furthermore an Auxiliary Transformer for feeding the machine power house auxiliaries. A circuit breaker has been foreseen on the 11 kV side of the auxiliary transformer, whereas the main transformer is connected through disconnecting switches only.

The generator is earthed through a voltage transformer, with suitable resistors connected in parallel.

For starting of the power house and to meet any emergencies during a complete shut-down, a 11 kV



The Machine Hall showing the three Hydro Generators.

supply from the Sengulam Power House, located about 3½ miles from Neriamangalam, feeds the common services busbars. Each generator auxiliary (Unit Board) is normally fed from its own auxiliary transformer, but in case of failure of this supply, the unit boards are automatically connected to the common services board. When the supply from the particular auxiliary transformer is restored, the Unit Boards are once again automatically switched back to this supply, cutting off the common services.

The main step-up transformers are rated for 18,000 kVA, 11/110 kV and are provided with on-load tap changers on the high voltage side. The transformers are designed for natural cooling up to 75% of the rated output, and at higher loads, the battery of cooling fans is automatically switched on.

Considering the various advantages and the maintenance facilities it offers, airblast circuit breakers have been chosen both for the 11 kV indoor and 110 kV outdoor installations. The 110 kV outdoor breakers have a rupturing capacity of 2,000 MVA which can be increased to 3,000 MVA at a later stage, if required, simply by the installation of additional resistors.

The breakers are suitable for single, as well as, three-phase auto-reclosing. Reclosing relays have been provided for all the four outgoing transmission lines.

For the outdoor yard, a double busbar system has been adopted and it has been possible to have a neat layout by using stranded copper conductors for the busbars as well as the jumper connections. A set of 3 single-phase PTs, connected to each busbar, gives the potential supply for metering and synchronising.

The protection scheme is very modern, fulfilling all the operational requirements. A gist of the various protections for the different equipment is given below:

(a) *Generators:* Differential, over-voltage, thermal overload and overcurrent, stator earth leakage, rotor earth leakage and field failure protection.

(b) *Transformers:* Winding temperature, Buchholz and differential.

(c) *110 kV Transmission Lines:* High speed distance relays with overcurrent and earth leakage back up protections.

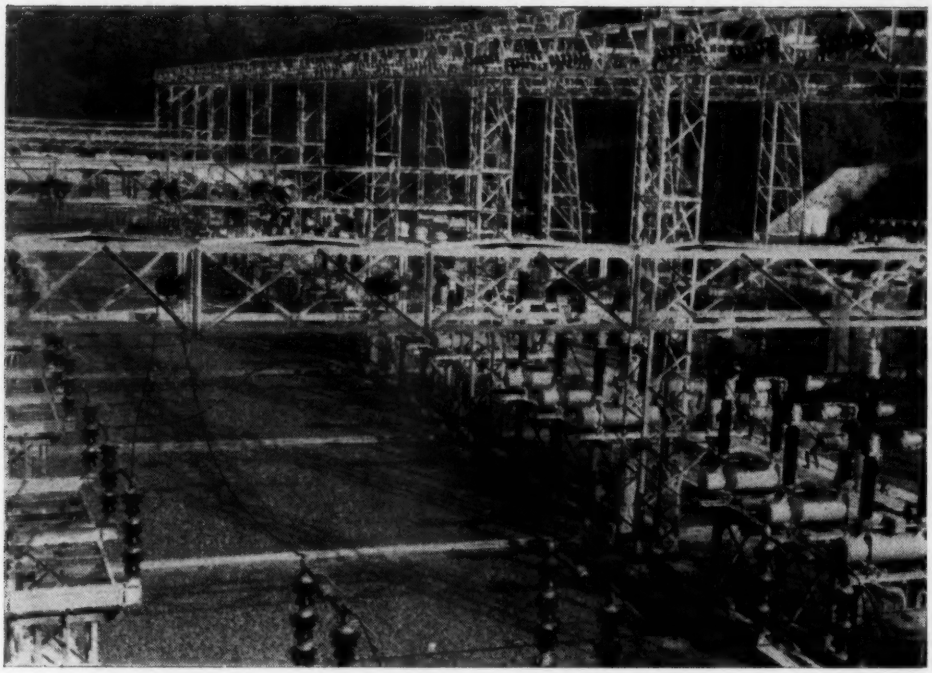
(d) *Auxiliary Transformers:* Overcurrent.

Special mention may be made here of the 'Brown Boveri' Distance Protection which has been adopted by the Kerala State Electricity Board for their complete 110 kV, as well as, a good portion of their 66 kV net-work. The relays have an extremely short operating time, about 3 cycles, and do not require any back-up protection. The D.C. supply is by means of a 110 V station type battery, with an automatic charging equipment. The charging is done by motor generator sets, as well as a trickle charger.

The control room is situated on the second floor in the power house from where a complete view of the machine room can be had. Below the control room is located the cable room where the cables have been routed to the different panels/desks above by supporting them on steel racks. This offers an extremely well laid out cabling arrangement which facilitates maintenance work also. All the controls indicating instruments and mimic diagrams are mounted on the control desk which is of a very compact design. The relays and integrating and recording meters are installed on the control panels which are arranged to give a very clear view to the Shift Engineer.

The 11 kV switchgear is located below the generator floor and the connections from the generator terminals to the switchgear effected by means of under-hung copper busbars. The 400 V switchgear and the Unit Boards for the machine are located on the generator floor itself.

The cooling water required for the generator air coolers, the generator bearing oil and the turbine bearings is obtained by 3 vertical borehole pumps which pump water from a sump situated on the tail-race side. Two of these pumps will normally meet



The Outdoor 11KV Switchyard.

with the cooling water requirements of all the 3 machines and the third one is used as a standby. The governor oil pumps as well as the generator thrust bearing cooling pumps normally are driven by A.C. motors, but in case of A.C. failure, the D.C. motors automatically come into operation.

Synchronising can be effected either by hand or by the automatic synchroniser. The principle of working of the automatic synchronising apparatus can be summed up as follows:

It measures the slip between the two nets which have to be synchronised and applies the impulse for the breaker accordingly. The time between the application of the impulse to the main breaker and the pointer of the synchronoscope reaching the 12 o'clock position is a function of the slip and is determined by the apparatus itself. With the help of this apparatus, therefore, it is possible for even inexperienced personnel to synchronise the machines onto the net. It may be mentioned here that Neriamangalam Power House feeds into the Kerala Grid, which is fast expanding.

In view of restrictions on the maximum weight of any package for transport reasons, the stators of the generators were sent in two halves and the transformers were also despatched in a dismantled condition. The erection, therefore, posed many natural difficulties associated with such assemblies at site, but all these difficulties have been successfully overcome. As a matter of fact, in spite of the adverse weather conditions, it has been possible to complete the erection within the schedule foreseen and sometimes even improve upon the schedule, due to the efforts exercised by the client's Field Engineers as well as Brown Boveri-Voltas erection personnel.

The Neriamangalam Project has been engineered by the Kerala State Electricity Board under the able guidance of Shri K. P. S. Nair, now a Member of the Central Water and Power Commission and Shri A. O. Oommen, Chairman of the Kerala State Electricity Board.

The successful implementation of the Project means more power for large and small industries, rural electrification and domestic consumption in the southern-most State of India.

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2. The original copy of the manuscript, and not a carbon copy, must be submitted. Mathematical symbols and Greek letters should be inserted in ink clearly.

3. The length of a paper will naturally depend on its subject matter but it should be as short as the nature of the subject will allow. *Brevity is the essence of a good contribution.* There should be no undue recapitulation of well-known first principles or engineering theory and practice. The length of an article is limited to 5000 words. Papers of 5000 to 3000 words will be very acceptable. Each paper must give an *abstract (not an introduction) in about 150 words,* suitable for printing at the head of the paper.

4. Manufactured products should not be referred to by a maker's name or a trade-name unless that is unavoidable.

5. The contents of a contribution should usually be arranged as follows:

* (a) Title
(b) Table of Contents
(c) Abstract
(d) Main Text
(e) Conclusions
(f) Acknowledgments
(g) References or Bibiliography

* The title of paper should indicate briefly the main subject. When writing his name beneath the title, the author should give particulars of his professional position, or occupation and indicate his rank.

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7. Abbreviations and symbols should conform to accepted standards. If any phrase or word, not commonly abbreviated, is abbreviated for convenience it should be explained when first used.

8. Section headings, sub-headings and paragraphs should be inserted to divide the text into its natural parts.

9. Extended mathematical proofs, digressions and detailed explanations of methods, tests etc. should be excluded; they can be added, if necessary, in the form of appendices. Long quotations should be avoided; normally, a reference to the original publication in the text should suffice.

10. References must be complete and accurate. The details required are:—

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The authors will be normally supplied with 20 copies of off-prints free of charge for their article. If more off-prints are needed, they should intimate their requirements at the time of sending their contribution.

The 275|400 kV West Thurrock Crossing

DESIGNED AS A MAJOR STAGE IN THE DEVELOPMENT of the 275 kV Supergrid in Southern England, considerable interest attaches to the 275/400 kV West Thurrock Crossing of the River Thames.

This crossing is an essential part of the continuance of the supergrid into South Eastern England and will also form at the same time a major step in the closure of the 275 kV "ring" around London. The new line, of which the crossing forms a part, starts at the C.E.G.B's 275 kV station at West Thurrock on the North bank of the Thames and is carried over to Northfleet by the special conductors of the crossing before continuing as a standard 275 kV line via Canterbury to Lydd with connections to the cross-channel cable link and to the Nuclear Power Station now under construction at Dungeness. Its design and erection has taken account of the Board's recently announced policy of uprating the supergrid from 275 kV to 400 kV, a policy which has been adopted in order to increase transmission capacities and to minimise the number of grid lines required, thus reducing interference with amenities to a minimum. In essence, the crossing consists of two 615 ft. towers of high tensile steel which support the conductors at the necessary height to gain the stipulated river clearance, and two anchor towers which take the strain of the crossing conductors.

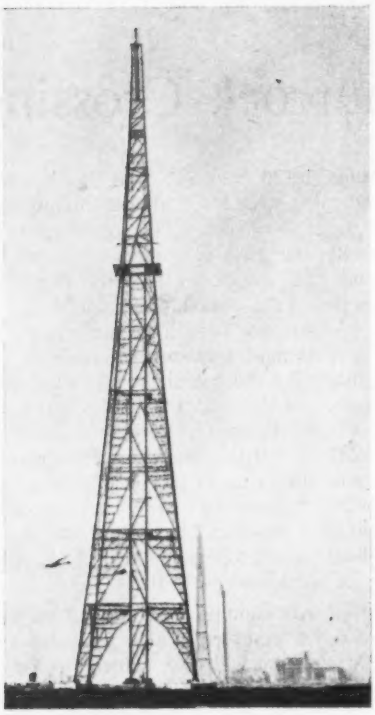
The selection of a site for the crossing and the conploys for the 275 kV supergrid are twin 0.4 in² steeland conductors was the subject of extensive studies by the transmission line design engineers of the C.E.G.B. Due to the special position of the Board in the U.K. with regard to the generation and transmission of electrical power, the Board's staff fulfills a consulting role, drawing up the overall design parameters, investigating and supervising detail design and construction. This in considering the design factors for the crossing, it was apparent at an early stage that the site between West Thurrock and Northfleet was the most suitable for this crossing. It was also obvious that, due to the 4,500 ft. of the span and the fact that a minimum clearance of 250 ft. between the lowest point of the span and the mean high water was required by the P.L.A., special attention would have to be given to the conductor tower design.

The standard conductors which the C.E.G.B. employs for the 275 kV supergrid are twin 0.4 in² steel-cored aluminimum conductors per phase. Whilst these would not provide sufficient strength for the 4,500 ft. span of the crossing, the experience gained by the Board of this type of conductor led to the development of a 199 stranded, steel cored conductor, using 91-120 tons/in² grade steel wires as a core with 108 strands of aluminium arranged in 3 layers over the core. This conductor matches in capacity the twin conductors of the incoming lines and has sufficient diameter (2.262 ins.) to accommodate the maximum operating pressure of 400 kV without corona losses arising. Its high mechanical strength necessary to obtain an economic sag, is shown by the calculated ultimate strength of 290,000 lb., and the modulus of elasticity at 14.25×10^6 lb/in². Its maximum working tension is 97,200 lb. In working out the design, account was taken of aeroynamic effects as might be expected with long spans of this nature in addition to the more routine meteorological aspects. The design radial thickness for ice loading is 0.5 in. and the wind loading figure on 80% of wind span is 15 lb/ft.².

A central over-running earth wire of the same construction as the conductors will be employed on the crossing. This wire will give a shielding angle of 45° and by using a conductor for this duty, uniform mechanical characteristics and economic life are obtained together with a measure of convenient interchangeability. The conductor has been manufactured by British Insulated Callendar Cables Ltd.

The two crossing towers are square in plan, the height being 615 ft. and the base being 100 ft. square. The overall length of the top cross-arm is 74 ft. Each tower consists of 21 main leg sections, these being between 25 and 31 ft. in length, making eleven panels. The first lower five panels take the form of modified K bracings, these being followed by a series of open diamond and scissor braced panels. The graceful shape of the tower is governed by a change of leg slope at every second panel, i.e. every 125 ft.; it was both convenient and desirable to use such an interval to enable aircraft obstruction lights to be sited at the main horizontal bracing members at these levels, thus achieving support for the access catwalks to the lights.

At the top of the third pair of panels (375 ft.) is located the main "half-way house" maintenance platform which will carry an overhead track and trolley plus winching equipment for lifting the assembling spare insulators. Further maintenance lifting gear is located at the top of the tower, this being supported by a special cross-arm located above the topmost conductor crossarms at 31 ft. 3 in. intervals. A particular feature of the towers is the 15 ft. sq. central column which is carried up as far as the 375 ft. maintenance platform. This column was designed to assist in the erection of the six lower panels of the tower by providing a base for the derrick and also to give



Erected for the C.E.G.B. by British Insulated Callenders' (Construction) Co., these Thames crossing towers are 615 ft. high.

a structure around which a central stairway could be built of standardised units, with radiating catwalks out to the aircraft lighting panels. They also form central lifting wells for maintenance material and equipment.

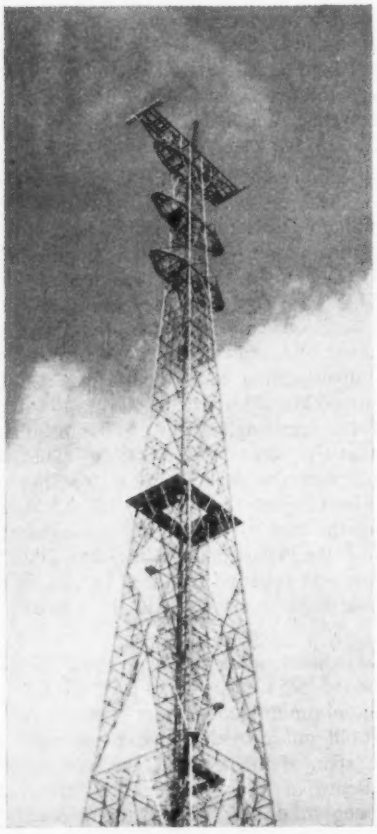
The steelwork comprises standard, galvanised, high tensile steel rolled sections conforming to BS. 548. It has been fully site assembled and of particular note has been the smoothness by which site assembly has been marked, resulting from extremely fine tolerances of manufacture.

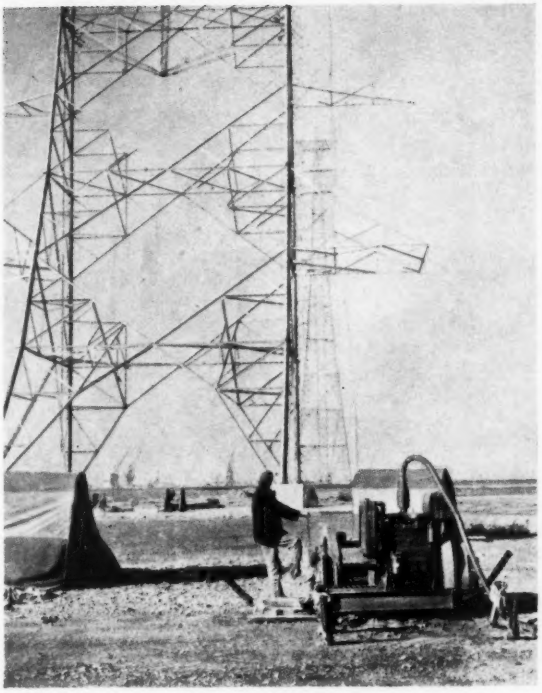
The anchor towers are also fabricated from high tensile steel, these towers each consisting of four panels of 30, 41, 41, and 33 ft. high, each panel forming an open diamond structure. The function of these towers is that of a frame to which the crossing conductors are secured. They are, however, provided with three pairs of auxiliary crossarms which support the 'jumpers' or connections between the incoming lines and the crossing conductors. The detail design of both crossing and anchor towers was carried out by Blaw Knox Ltd.

Mounted at the end of the suspension tower crossarms are universal bearings from which the insulator assemblies are hung. These insulator assemblies manufactured by Bullers Ltd., will have jacking equipment to allow the insulator strings to be removed for servicing, and inspection of the universal bearings will also be possible without disturbing the insulators. The suspension assemblies on the crossing towers consist of six insulator strings in parallel, and the tension sets have eight parallel strings, all the insulator assemblies incorporating level balancing between strings and being designed for equal load sharing in the event of one string failing. Each string consists of 20 porcelain units in both the suspension and tension sets, two extra units being fitted to each tension set to improve the wet flashover values due to the bunching of eight strings in one assembly. The diameters and centres of the units are 14 in. × $6\frac{3}{4}$ in. in the suspension sets and $12\frac{3}{4}$ × $7\frac{1}{2}$ in. for the tension sets, the overall length being $275\frac{1}{2}$ and $294\frac{3}{4}$ in. respectively. Ball and socket insulator couplings are used throughout. The ultimate load figure for the suspension sets is 180,000 lb., whilst that for the tension sets is 240,000 lb.

The foundation work for the towers was started on both sides of the river early in 1959, tower construction commencing in August 1959. The founda-

Top section of a crossing tower, showing conductor crossarms and maintenance platform.





Anchor tower steelwork being raised with a Sykes double barrelled winch.

tions for the crossing towers consisted of 30 reinforced concrete piles, each 17 in. square, at each of the four legs of the tower, and at the anchor towers 100 piles are provided at the rear to resist overturning forces. The piles were taken 40 ft. deep on the North side and 45 ft. deep on the South bank. The survey work in connection with setting out the towers was particularly intricate, this being borne out by the fact that all four towers are aligned to within $\frac{1}{4}$ in. over a total length of 7,700 ft. The crossing span is 4,500 ft. and each anchor span is 1600 ft. The spans were checked with a geodetic theodolite, a telurometer being finally used to check span distance over the 4,500 ft. to within 3 in. The exceptional accuracy of alignment was obtained by mounting neon tubes vertically on masts at each site and aligning these by night-time theodolite observation under V.H.F. radio control.

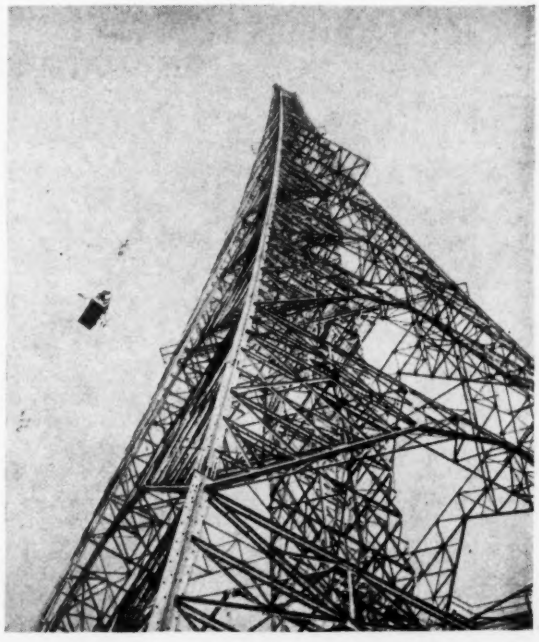
The building of each crossing tower by British Insulated Callendar Construction Co. Ltd., began with the erection of the first 125 ft. of the central column and upon this an 80 ft. derrick was mounted in a lifting rig for the erection of the first 60 ft. panel of the tower. When this panel was complete the central column was erected another 60 ft., the luffing derrick was also lifted up 60 ft., and erection was continued on the second panel of the main structure. Above 350 ft., this derrick was later used as a floating rig for the main construction. The structure uses G.K.N. high tensile bolts run with ratchet spanners.

The winching duties for raising all men and components at the crossing towers is carried out by a modified Sykes No. 8 winch powered by a Lister F.R. 4 engine. A further Sykes No. 7 winch powered by a Ruston 3YC engine is used as an auxiliary on each tower. The main Skyes winch is reeved on a 3:1 reduction tackle, the maximum lift to date being $3\frac{1}{2}$ tons. The maximum bond length is 4,100 ft., the drum speed being 120-150 feet per minute, giving a lifting speed of 40-50 feet per min. The bond used is $\frac{1}{2}$ in. diameter steel wire rope in 10 laps. At the anchor towers the main winch is a Sykes No. 7 winch, the auxiliary being a No. 6 size. The main winch here is reeved as at the crossing tower and the maximum lift of 3 tons will be for the top main truss. A 3,000 ft. bond length was provided with this winch to enable it to be used for lifting the insulators of the main tower. Of particular note are the safety brakes used with the winches to guard against any mishap should the winch operator be suddenly incapacitated as for example in the event of an electrical discharge down the tower and along the bond. The safety brakes employed are so arranged that they are normally in the applied position and are released by feet pressure. This control is quite light in order that the operator shall not become fatigued during the long hoists necessary.

The most intricate section of the construction of the crossing towers was the erection of the top maintenance crossarm, which required an additional derrick at the 600 ft. level. The crossarm was erected,

(Continued on page 36)

Design of tower steelwork was carried out Blaw Knox.



Book Review

The Electricity Supply Act, 1948 by Naushir Bharucha, published by Bombay Presidency Association, Opp. University Building, 107, Mahatma Gandhi Road, Fort, Bombay, Pages—490, Price Rs. 30/-.

With the development of electrical power in the country at a rapid pace the pattern of its administration is naturally changing from the pre-war manner. The ownership and initiative have shifted more and more from the private to the public sector as will be indicated by the fact that of Rs. 975 crores allotted to Power in the Third Plan only Rs. 50 crores will be in the private sector and the rest in the public. Apart from this, the policy of taking over private companies generating power is also being pursued in many States.

Thus the Electricity Boards which have now been set up in all the States are becoming more and more prominent and powerful in the administration of electricity in the country.

In view of this development, it has become necessary for engineers, administrators, accountants, private supply undertakings, and the legal profession to study the Electricity Supply Act in all its implications. The author, therefore, has done well in bringing out this exhaustive study of the Act, which will fill a great vacuum.

Among other matters the book deals with the question of nationalisation of private sector in electricity supply, the position of public sector, that is mainly the powers of the State Electricity Boards vis-a-vis the private licensee; the method and manner of assuring control of private stations designated as 'controlled stations'; of permanently closing of such stations; purchase of undertakings and the basis of compensation for such compulsory acquisition; determination of the costs of generation and allocation of such costs between 'fixed costs' and 'running charges'; the financial principles for determination of 'reasonable return'; 'clear profits', allocation to depreciation and formation of various Reserves; or the problems peculiar to the electricity supply industry such as 'deferred tax liability' or effect of changes in the pattern of Company taxation introduced by the Finance Acts of 1959 and 1960. Of interest to the consumer, that is the public at large, is the treatment of financial principles relating to pricing policy, the obligations of the electricity supply companies towards the consumers and their liability to provide a reliable and efficient service at reasonable cost.

Another feature of the book is that it extensively draws upon the laws in the U.S. and British Courts and makes detailed reference to the Herbert Committee's Report in the U.K. and to the views of Prof. I. R. Barnes of the Yale University.

We have no hesitation in recommending this book to all concerned as extremely worthwhile.

Current Engineering Practice : Special Number on High Voltage Power Transmission and Protection against Surges, Managing Editor, Mr. K. Janakiraman, published by Current Technical Literature Co. Private Ltd., India House, Opp. G.P.O. Bombay-1, Pages 202, Price, Rs. 15/-.

The Special Number of this Journal covers the proceedings on the subject of "high voltage power transmission and protection against surges" symposium held on the occasion of the Golden Jubilee of the Indian Institute of Science, sometime in January, 1960. The symposium was chaired by Sri N. N. Iyengar and inaugurated by Mr. M. Hayath, Chairman of the C.W. & P.C. It contains 27 papers by eminent engineers such as, V. Venugopalan, Prof. F. R. Perry, Prof. R. W. Atkinson, Prof. F. N. Prangnell, and Prof. D. J. Badkas. The symposium had been divided into 6 sections in each of which several papers suitably grouped were discussed. Brief reports of this discussion have also been added at the end of each group of papers.

All in all the issue is a heavy volume of competent papers on the topic and should be extremely useful to power engineers.

India in Industries published by the Indian Market Research Bureau, 15, Park Street, Calcutta-16, Pages 136, Price Rs. 15/-.

This purports to be the 4th Engineering issue of this quarterly Journal. A number of articles such as Hydraulic Problem Solution by Electric Analog Computer, Power Development in Eastern Zone, Hydraulic Research, Low Temperature Carbonisation of Coal, etc. are followed by brief survey of industries such as Iron and Steel, Non-Ferrous Metals, Power Resources, Transport Industry, etc. have been included. Although all this material gives some broad idea of the subjects covered they do not seem to be exhaustive either for purposes of reference or specialised study. Too many topics seem to be covered in one issue and naturally the issue seems to lose its balance. The sponsors call this a Research Bureau offer but the product that they have brought out lacks any such attitude.

Editorial

Power Research in India

NOBODY can complain that development and organisation of scientific research in India has not proceeded fast in this country in the last decade or two. Ever since the Council of Scientific and Industrial Research was established in 1942 quite a large number of national laboratories have been established and research work extended in many directions. Today there are 24 national laboratories, 100 research institutions and research centres, over 50 associations for technological research and some 40 universities pay substantial attention to science and scientific investigations. Such a rapid development in the last 20 years, mainly in the last 10 years, is partly due to the active policy of the Government of India "to foster, promote and sustain by all appropriate means the cultivation of science and scientific research". The personal interest that our Prime Minister takes has also been an inspiring factor.

However, compared to the enormous expansion and attention given to scientific research in other countries we are still lagging far behind. Consider for example, some of the following figures. The U.S. allotted about 153 million dollars in 1960 compared to 3.5 million dollars in 1951. Norway has stepped up expenditure of scientific research by 4 times in 1958 compared to that in 1946. Similarly Canada has stepped up 20 times compared to its figure in 1939.

In the last decade or more we have spent hundreds of crores in river valley projects. For example, during the Second Plan we have spent nearly 900 crores in this field, but our expenses for research under irrigation and power have not exceeded 3 crores, which comes to less than .3 percent of the total outlay.

In the Third Plan an allotment of 4 crores has been made for research in irrigation and power. But the outlay for development projects in this field is over 1500 crores. Thus the expenses for research comes to no more than .25 percent of the outlay. That is, the proportional expenditure during the Third Plan on research have gone down instead of being stepped up.

In our country at least 19 irrigation research institutes are carrying on their studies. Irrigation research has come to stay and has proved itself to be quite worthwhile. But power research has hardly begun. For quite a long time this field had been neglected. But it is encouraging to notice that serious attention is now being given to it. Apart from the schemes for research on a central level being undertaken at Bangalore and Bhopal, the authorities are considering their expansion on a regional basis also. But compared to the needs of the country and to the rapid pace of development of power, both generation, transmission, distribution and utilisation, the progress is rather slow. A paltry sum of Rs. 30 lakhs has been allotted in the Third Plan for research on power problems by the various State Electricity Boards. Although it is a good beginning, it is our view that the total funds allotted for power research should be considerably increased. Some of the Universities and reputed Engineering Colleges should be associated with power research. The private generating firms of major size in this country can also play their part.

Although we have stressed only the financial aspect of research here, we believe that major attention in the initial stages should equally be given to create a nucleus of good research workers. This depends entirely on the first guides. If in considering this aspect it is thought worthwhile inviting competent foreign scholars, there should be no hesitation in doing so. But another aspect clearly merits consideration, namely, the most meritorious and research-minded among students should be picked up and persuaded to enter the research field, and in this matter the service conditions should be sufficiently attractive, so that they are not detracted into other fields of the profession for a decent living.

Our Contributors

Mr. J. L. Watts received his technical education at Manchester College of Technology, concluding with the award of the Associateship of that College. After practical training with Metropolitan - Vickers Electrical Co. Ltd., of Manchester (now a member of the Associated Electrical Industries Group) he spent some time in the design offices of this company.

In 1927 he joined British Engine Boiler, and Electrical Insurance Co. Ltd., as Assistant Electrical Engineer in their Midlands Office. Since 1932 he has been an Electrical Engineer-Surveyor with this company, first in the Manchester area and later in the Southampton district, being concerned with the safe and efficient operation of various types of electrical machines and plant in many industries, investigation of causes of breakdowns, etc. He is the author of many articles and of the books *Electric Motor Control Gear* and *Electrical Maintenance and Repairs.*

Mr. Harbans Singh, after completing the Electrical Technology Course at the Indian Institute of Science, Bangalore, conducted research work for a short while at the same Institute. During 1943 and 1944, served in the American aerodrome, Agra and the Indian National Airways, New Delhi. Joined Punjab P.W.B. in 1945 as an Assistant Engineer. From 1947 to 1952, worked as Assistant Inspector and thereafter for about a year as Assistant Sales Engineer. On promotion as Executive Engineer in 1953, he was put in charge of the Commercial Working of the Electricity Branch including the Bhakra Nangal Project in the capacity of Sales Engineer and continued on this post till mid 1959. Since then he is working as Executive Engineer, Patiala Division, Patiala.

(Continued from page 33)

THE 275/400 kV WEST THURROCK CROSSING

section by section, 615 above the ground, early sections being stayed. When this unit was completed, the six lower insulator crossarms were raised into position. These units each weighed 2½ tons and were pre-assembled on the ground.

The running of the conductors also present certain facets of interest. The procedure to be adopted will consist of laying a track and haulage rope in the river, with each end being passed over the tops of the crossing towers on wheeled paddles. At times agreed with the P.L.A., the river will be closed and these ropes will be hoisted out of the water and tensioned by winches and tackle at the rear of the anchor towers. The haulage rope and track rope will then be "stitched" together by means of a set of trolleys which run on the fixed track rope and are pulled by the moving haulage rope. When the system is completely stitched and ready, it will carry the conductors by means of a further set of suspension trolleys which will be hauled over the crossing, the suspension trolleys being fed on at one end and the stitching trolleys being removed at the other end. The conductor drum will be mounted on the North bank and the haulage winch on the South bank. (All operations will be directed by V.H.F. radio control and there will be as many as six radio sets maintaining contact between the teams on the ground, at the tower top and on the opposite side of the river). One of the conditions of the contract is that no conductor shall touch water or land at any stage, this being necessary due to the need to prevent any possibility of damage to the cables and thus giving rise, amongst other things, to corona losses. As each conductor is received across at the far anchor tower, it will be tensioned at both ends and released from the suspension trolleys, this is possible as the sag of the track rope system will be greater than the sag of the conductor in its service position. Tension and suspension insulators will then be inserted at the anchor and crossing towers and the track rope and trolley prepared for the next conductor by reversing the haulage rope, re-attaching the stitching trolleys and recovering the suspension trolleys at the North bank anchor tower.

The main contractors for the C.E.G.B. are British Insulated Callendars Construction Co. Ltd., the detail tower design being by Blaw Knox Ltd. Steelwork for the suspension towers was fabricated by Horsley Bridge and Thomas Piggott Ltd., whilst that for the anchor towers was fabricated by Painter Bros. Ltd. The foundation design consultants were Sir Alexander Gibb and Partners, the foundations being emplaced by Holloway Bros. Ltd. and Mears. Bros. Ltd. The conductors are being supplied by British Insulated Callenders Cables Ltd., and the conductor erection equipment by John Barnsley & Co. Ltd. The anchor clamps, armour rods and vibration clampers are supplied by Alcan Industries Ltd., the insulator assemblies being manufactured by Bullers Ltd.

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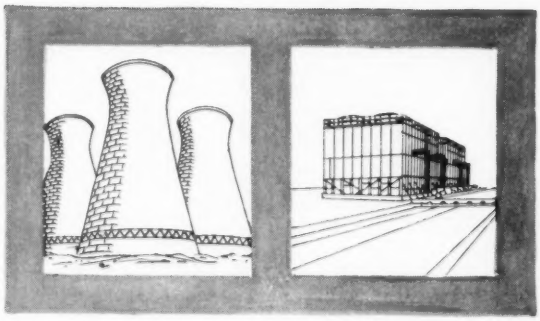

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